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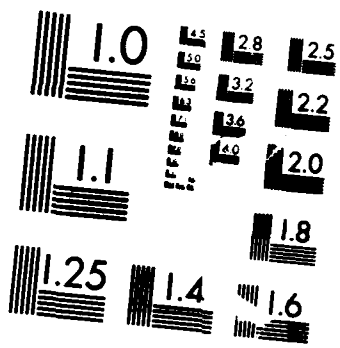

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THE USE OF CONCURRENCY IN THE ACQUISITION PROCESS AND ITS IMPACT ON RELIABILITY AND MAINTAINABILITY

THESIS

John A. Ross
Captain, USAF

AFIT/GLM/LSMB/87S-62

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the degree of

Master of Science in Maintenance Management

John A. Ross, B.S.

Captain, USAF

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John A. Ross

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Abstract

The use of some degree of concurrency in weapon system acquisition has become a normal mode of operation. There are several benefits and problems associated with concurrent programs. The recent elevation of reliability and maintainability (R&M) to a status equal to performance, cost, and schedule when evaluating current weapon systems has added to the list of potential problems experienced by concurrent programs.

A literature review was conducted which traced the history of concurrency from the Ballistic Missile Programs to the 1986 Packard Commission Report. This review focused on the reasons for the continued discussions on the overall value of concurrency. The review also looked at the impact of concurrency on system R&M. Several factors were identified which existed in concurrent programs and showed a potential to limit system R&M. In addition the study covered the causes for the variances between the system R&M measures demonstrated in the developmental,and operational environments.

The researcher interviewed fifteen managers who were involved in five concurrent programs. These managers were from the following areas: the System Program Office, Deputy

Program Manager for Logistics, and the Air Force Office for Test and Evaluation. The interviews focused on the opinions of the managers on concurrency's use and how it affected R&M development in their program.

The results of this study indicate that concurrency does impact system R&M development. However, the amount of impact and the applicability of the factors reviewed varies by program. Managers' opinions of the factors appear to be influenced by their position in the acquisition program. The benefits and problems of concurrency are covered. The causes for the disparity between field and development R&M measures, suggestions to correct this R&M problem, and recommendations to improve system R&M are discussed.

THE USE OF CONCURRENCY IN THE ACQUISITION PROCESS AND ITS IMPACT ON RELIABILITY AND MAINTAINABILITY

I. Introduction

General Issue

In June 1985, the General Accounting Office (GAO) released a report titled "Production of Some Major Weapon Systems Began With Only Limited Operational Test and Evaluation Results." The report identified nine systems and claimed that the high use of test concurrency had produced inconclusive data to prove system adequacy (5:44). While the Department of Defense (DOD) partially concurred with the GAO findings, DOD maintained that the United States' acquisition process usually produces highly capable weapon systems (2:41). Test concurrency is being used more and more in weapon system development (5:43). Does concurrency result in inadequate operational test and evaluation results?

Background

The use of concurrency in the DOD acquisition process has sparked controversy for the last three decades. While a form of concurrency had been used by industry, the first use of the term by DOD seems to have occurred in 1958 with the Ballistic Missile Program (23:67). A 1959 report titled "The United States Guided Missile Program" prepared for the Senate Armed Services Committee addressed concurrency as:

> [The Air Force]... has adopted and expanded another technique often used by industry where competition in getting to a market is keen; that is compressing the periods of development of new products and getting production started. In the case of the missile program ... the Air Force is undertaking to do this by what they call the "concept of concurrency" (23:67).

The concept of concurrency was teamwork applied with modern management techniques. The use of concurrency would provide:

> ...an overlapping of the development functions so that, for instance, flight test can proceed coincident with production, construction can get underway while flight test is in progress, and training can be initiated concurrently with testing and production (42:238).

Besides the Ballistic Missile Program, the U-2 and SR-71 aircraft were developed using concurrency. The successful development of these programs brought the use of concurrency solidly into the DOD acquisition process (16:42; 28:56).

The success of concurrency was short lived. Many programs developed during the 1960s experienced both cost and performance problems (7:48; 16:52). Deputy Secretary of Defense David Packard identified several acquisition problems in systems developed prior to 1969. These were cost overruns, excessive time from conception to delivery, and low reliability (40:3). In almost every program where production was started before development and testing was completed, both money and time was wasted (12:4). Since production was started before completion of development, costly engineering changes had to be accomplished on the production line (40:4). In 1978 the Defense Science Board defined concurrency as:

> The conduct of steps leading to production before the end of full scale development time span. The steps referred to include: manufacturing planning, process development, tool and test equipment design, and fabrication and ordering of long-lead materials (7:47).

Concurrency was identified as the cause for these cost and performance problems (23:68; 40:3).

Consequently, Mr. Packard introduced an acquisition policy which rejected the use of concurrency and required the use of prototypes. The DOD would use a sequential acquisition process (16:53-54). Weapon system acquisition would be accomplished in three phases: program initiation, full scale development, and production/development (35:22-24). According to an article by Robert Gibson, a 1971 Rand report recommended:

> A sequential approach to major system acquisitions with clearly defined milestones. The normal strategy for system acquisition in the 1970s should involve a conscious decision to produce (or not produce) only after the development is complete (23:68).

David Packard's acquisition policies failed to correct all the problems of the DOD acquisition system. Due to an increasing acquisition time cycle, a Defense Science Board report in 1978 stated:

> That the acquisition process has gone to unreasonable limits in discouraging concurrency and in over emphasizing advanced development prototypes even when these add more to program cost and acquisition time than they benefit it by reducing risk (7:V).

Although considered successful, prototype programs such as the F-16 and the A-10 resulted in acquisition times of nine and eleven years, respectively (52:110). Concern was expressed over the growing length of time to develop new systems. The acquisition cycle was taking from 12 to 15 years to produce new systems while modern commercial aircraft were being developed in about 8 years (47:3-4). Many of today's weapon system acquisition programs use a combination of concurrency and prototyping (54:40-41). A review of Government Accounting Office reports showed that DOD acquisition programs continue to experience problems (19; 20; 21). Current acquisition problems have been identified as excessive time and cost, along with the need to improve performance and readiness (1:2; 16:68-70).

Specific Problem

Concurrency has become a factor in almost all major weapon system acquisitions. Reviews of the acquisition process have been accomplished to determine the reasons for continual problems. Numerous policy and organizational changes have been implemented to make the DOD process more efficient, cost effective, and to shorten the length of the acquisition cycle. Actions to reduce acquisition times may conflict with steps to improve system reliability (47:9).

Since current system development programs take up to ten years or more, the increased emphasis on reliability and maintainability (R&M) initiated in the 1980s has not been conclusively evaluated. There is a requirement to determine if the use of concurrency during system acquisition and the need for improved R&M are compatible. What impact does concurrency have on our acquisition programs and system R&M?

Scope of Research

This study will review the use of concurrency in system acquisition. A literature review will be accomplished to identify the reasons for the fluctuating management support of concurrency. Interviews will be conducted with managers involved in the acquisition process from Air Force Systems Command (AFSC), Air Force Logistics Command (AFLC), and the Air Force Operational Test and Evaluation Center (AFOTEC). These interviews will provide information from three different management perspectives. The managers from AFSC will provide data from an overall system responsibility aspect, AFLC provides a primary focus on logistics support, and AFOTEC will provide information from the operational testing standpoint. This study will focus on reliability and maintainability during system development.

Research Questions

During the analysis of concurrent programs, the researcher will answer the following questions:

1. What weapon system programs were successfully developed using concurrency?

2. Why has the use of concurrency been periodically accepted and rejected?

3. What are the resulting benefits of using concurrency?

4. What are the potential problems associated with the use of concurrency?

5. How well do the quantitative R&M indicators developed during testing predict field R&M experience?

The interviews of acquisition managers will be designed to determine:

6. How does the use of concurrency affect acquisition programs?

7. How does concurrency impact system reliability and maintainability?

8. What can be done to improve system R&M in the acquisition process?

Summary

The attempts to correct acquisition problems have centered around two main factions. Air Force and DOD managers have been divided into two groups, those who favor accelerated development programs and those who want a sequential process. This difference of opinion has resulted in policies and directives from one extreme to another either supporting concurrency or rejecting it (8:I-2).

Col Bradson in an article for Program Manager explained the need for concurrency was due to the rapid development of new technologies. Current acquisition programs taking 8 to 15 years to complete will span from 2 to 4 technological generations (3:12). There are some people in the acquisition world who believe we have always used some degree of concurrency. Deputy Secretary of Defense Paul Thayer reportedly stated:

> "The old myth, fly before buy, was just that,"... "It is a myth. It's never been practiced in pure form. There has always been some concurrency in any program I'm aware of. If you did wait until development and operational testing was complete before going on to large scale production, the system would be obsolete" (2:26).

Today's acquisition process uses concurrency. The degree of concurrency is dependent on the individual program's risk and how soon it is needed (37:46). A review of the literature to determine concurrency's affect on acquisition and R&M is warranted.

II. Literature Review

The purpose of this chapter is to review the use of concurrency in the Department of Defense (DOD) weapon system acquisition process and to look at the emergence of reliability and maintainability as performance factors. The weapon system acquisition process is defined as:

> A sequence of specified decision events and phases of activity directed to achievement of established program objectives in the acquisition of Defense Systems and extending from approval of a mission need through successful deployment of the Defense System or termination of the program (31:1).

Concurrency

The term concurrency has had many definitions since its origin in the 1950s. According to Captain Wayne Foote, in a Management Consulting and Research, Inc. report titled "Shortening the Acquisition Cycle: Research on Concurrency" concurrency is interpreted as:

> 1) parallel (back-up) technology development
> 2) simultaneous, but independent, technological development and testing,
> 3) co-production, and
> 4) overlap of dependent, normally sequential activities (16:3).

In the area of the weapon system acquisition process, concurrency can be defined as a strategy which results in the overlap of some or all the process phases. Today, these phases are concept exploration, demonstration and validation, full scale development, and production and deployment. Varying degrees of concurrency have been used in DOD acquisition programs for the past thiry years. During this time frame, concurrency has been credited with both fixing and causing many of the problems in DOD system acquisition. A historical review of some of the programs and outcomes resulting from the use of concurrency follows.

Concurrency: Initial Successes

Concurrency had its origin with the advent of the nuclear age and the successes of the German and Soviet Union scientists in rocket propulsion. Several senior civilian and military leaders in the United States realized that the advantages of time and distance which enabled them to prepare for World War II could not be guaranteed in a future war. Also, the potential of a Soviet Union technological breakthrough which would produce the first intercontinental ballistic missile (ICBM) posed a serious threat to national security. Consequently, an urgent need surfaced to develop a better and quicker weapon system acquisition process (42:238).

To meet the potential threat to national security the Ballistic Missile Program was initiated. This program was to be managed using a new acquisition strategy called "concurrency" (49:12). The concept of concurrency was teamwork applied with modern management techniques. Many senior leaders felt this new strategy would allow the United States to develop an ICBM before the Soviet Union. The use of concurrency would provide for:

> ...an overlapping of the development functions so that, for instance, flight test can proceed coincident with production, construction can get underway while flight test is in progress, and training can be initiated concurrently with testing and production (42:238).

The Ballistic Missile Program was responsible for developing three missile configurations: Atlas, Titan, and Thor. Due to the numerous emerging technologies associated with development of the first ICBM and the normal acquisition procedures, the missile development was expected to take from 10 to 11 years (42:244). This projection was the catalyst in the decision to use concurrency in the Ballistic Missile Program. A concurrent effort would shorten lead time in the acquisition process. By reducing lead time, these new missiles would have an extended life expectancy and be less susceptible to technological obsolescence. The Ballistic Missile Program was considered extremely successful with the Atlas ICBM being developed and deployed within five years of program startup. The Thor, intermediate range missile, was even more impressive as it achieved operational status in four years (42:240,250).

Several management decisions contributed to the overall success of the ICBM program. The creation of an autonomous organization, the Ballistic Missile Division, was a significant deviation from the normal acquisition process. This organization had overall responsibility and authority for all aspects of the ICBM program. Management guidelines were established to provide for maximum priority and decentralization, minimum committee operation and red tape, and a level of authority commensurate with responsibility (16:17-18). This structure allowed management decisions to be made at the lowest capable level. The organization staff consisted of a small number of highly qualified personnel. To provide additional highly skilled scientific and technical personnel, an engineering group was obtained through a contract with the Guided Missile Research Division of the Ramo-Wooldridge Corporation. Another important element in the ICBM program was the use of competition during development (16:20-23).

Other extremely successful acquisition programs were developed during the 1950s using similar management techniques as the Ballistic Missile Program. Two well known examples are the U-2 and SR-71 aircraft. According to Dr. Richard P. Hallion, Lockheed's success was possible:

> Because of more streamlined management, smaller development teams, stringent review of mission requirements, and rigorous adherence to cost and time schedules (28:56).

Additional management principle similarities between the ICBM program and Lockheed's programs were:

1. Program manager had practically complete control.
2. Highly skilled personnel in project offices.
3. High level of inspection and testing by subcontractor and vendor. Limit duplication of inspection and testing.
4. Timely funding.

5. Mutual trust between military and contractor personnel fostering a close working relationship.

6. Limit access to the project and its personnel through appropriate security measures (16:44-46).

The successful development of the U-2, SR-71, and ICBMs brought the use of concurrency solidly into the DOD acquisition process (16:43-44; 28:56). However, many subsequent concurrent programs faced significant difficulties.

Concurrency Problems

Some of the first programs that demonstrated problems in using concurrency were the early cruise missile programs: the Snark and Navaho. These programs suffered from schedule slippage and technical problems. In the final outcome the Snark was completed six years behind schedule and Navaho was cancelled after a three year slip (16:28). The reasons for the failure of the cruise missile programs can be found in management philosophy differences when compared to the Ballistic Missile Program. Concurrency was introduced into the cruise missile programs through unplanned schedule compression. Additionally, the program managers were not given the same autonomy, responsibility, and authority as in the ICBM program (16:26-28).

From 1958 to 1970 acquisition programs were being developed with a concept called "category testing" (54:17-19). This testing consisted of two phases of development test and evaluation (DT&E) and a third phase covering operational test and evaluation (OT&E) (1:6). According to

Major Adams, concurrency was used to expedite the overall acquisition process through an overlap of the two DT&E phases. The OT&E phase was not conducted until after the production decision and the availability of production aircraft (1:6-7; 49:9).

In the 1960s concurrency became more entrenched in the acquisition cycle with the practice of Total Package Procurement (7:47). Total Package Procurement required a governmental commitment to production of a system at the time of contract award (54:43). DOD continued to move away from the principles which had allowed the Ballistic Missile Program to be successful. In an effort to streamline the acquisition process, Air Force Systems Command and Air Force Logistics Command were created. However, this reorganization was not able to reduce the levels of decision making or regain control of systems engineering from the contractor and place it back into the project office (36:17). Concurrency had been very effective with a maximum decentralization of authority and responsibility to the program manager level. The increasing centralization of authority and layers of management were making the acquisition process ineffective. Many systems under development were experiencing both cost and performance problems (48:2). The MBT-70, Main Battle Tank, and F-111B programs were cancelled after considerable expenditures. While the C-5A and F-111 programs continued to production, they had large cost overruns and performance problems (7:48; 49:12). Concurrency was identified as the cause of these acquisition problems (7:48; 16:52). Also, concurrency resulted in new aircraft with known deficiencies being delivered to operational units. These aircraft were flown under some restrictions until engineering fixes could be designed, tested, and incorporated. This is what happened in the C-141 program because of a problem with the central air data computer (54:25-26). The 1970s brought a move away from the use of wholesale concurrency.

Prototypes

Deputy Secretary of Defense David Packard introduced an acquisition policy which rejected the use of concurrency and required the use of prototypes. DOD would use a sequential acquisition process (16:53-54).

> In July 1970, the blue ribbon defense panel recommended, among other things, the following: More use of competitive prototypes and less reliance on paper studies. Selected lengthening of production schedules, keeping the system in production over a greater period of time so that incremental improvements could be introduced. A general rule against concurrent development and production efforts, with the production decision deferred until successful demonstration of developmental prototypes (7:48).

From 1970 to 1977 there were continual discussions and congressional reviews on the use of concurrency. According to Captain Foote, the military services were not ready to accept the increased acquisition time and costs associated with sequential acquisition. After rejecting the use of concurrency, Mr. Packard endorsed low-rate production of the F-15 prior to the completion of developmental testing. He established a policy of separate production rates. Under this policy, concurrency would be accepted with low-rate production but high-rate production would not commence until the system evaluation was completed (16:53-60). Several applications of prototype development have led to some very effective and successful systems such as the F-16 and A-10 aircraft (52:110). The avionics and cannon subsystems for the F-15 were acquired through a prototype competition (36:30).

As the debate over the use of concurrency continued, the ultimate decision level for acquisition programs progressed upward (36:18,22-24). Recommendations of the July 1970 Blue Ribbon Defense Panel resulted in the creation of the Defense System Acquisition Review Council and the policy to determine operational suitability of systems prior to making production decisions. Another outgrowth of the panel's findings was the creation of today's Air Force flight test program (54:27-28). The new flight test DT&E/OT&E concept calls for test concurrency. Under this program, DT&E and Initial OT&E (IOT&E) overlap, allowing contractor and Air Force personnel to evaluate system performance, specification compliance, supportability, and initial operational effectiveness prior to a production decision (1:8-9).

Despite the changes to the DOD acquisition process in the areas of management and testing, the acquisition cycle continued to lengthen (12:3).

Acquisition Today

In 1977 a Defense Science Board Task Force was commissioned to study the increasing time cycle of acquisition (7:iii). The Defense Science Board report released in 1978 stated:

> That the acquisition process has gone to unreasonable limits in discouraging concurrency and in over emphasizing advanced development prototypes even when these add more to program cost and acquisition time than they benefit it by reducing risk (7:V).

In analyzing 63 acquisition programs, the task force concluded that there was no clear correlation between concurrency and poor quality systems (7:49). The report further provided examples of highly concurrent programs which successfully met schedule, cost, and performance objectives (eg. F-5E, Polaris, Minuteman, Boeing 727) (7:50). In the final analysis, the Defense Science Board report endorsed the use of both concurrency and prototyping in the DOD acquisition process. The amount of concurrency and/or the decision to use prototypes should be based on the level of technical risk and/or national urgency in each acquisition program (7:47,54). Many of today's weapon system acquisition programs use a combination of concurrency and prototyping. Some examples of these combined programs are the B-1B, F-16 C/D, LANTIRN, and AMRAAM (5:44; 36:30; 45:7).

To complete this review of concurrency and the DOD acquisition process changes, requires a mention of two relatively recent events. The 1981 Acquisition Improvement Program (AIP), previously the Carlucci Initiatives, and President Reagan's Blue Ribbon Commission on Defense Management, the Packard Commission, have made additional changes and recommendations to correct problems in the acquisition process and structure. Acquisition problems continue to be excessive time, cost, and the need to improve performance and readiness (1:2; 22:63). Both the AIP and Packard Commission acknowledged the potential value of concurrency in the acquisition process. It is too early to determine the effects of the AIP and the Packard Commission recommendations on DOD acquisition (1:37-38; 16:72). One of the findings of the Packard Commission as summarized in the June 1986 Air Force Magazine was:

> ...that successful programs were marked by development times of four to five years-about half the average. They all share certain key traits: short, clear lines of command; strict adherence to program performance, cost, and schedule baselines; small, high quality staffs; limited reporting requirements; good communication with the end user; extensive use of prototyping and operational testing (26:31).

The recommendations of the Packard Commission will be implemented in the Advanced Tactical Fighter program. The results of this model program may provide the answers to our acquisition problems (51:86).

Concurrency Pros and Cons

According to Colonel Bradson, the AIP places increased emphasis on concurrent activities especially in the areas of DT&E and OT&E (4:173). The 1978 Defense Science Board acknowledged the benefits of concurrency by reporting:

> A certain amount of program concurrency can contribute to the shortening of the acquisition process, with the attendant savings in total acquisition cost and an increased return on investment in terms of the availability of modern tools....for a longer period of time before obsolescence (7:46-47).

In the Fleet Ballistic Missile program concurrency benefits included: lower cost, early design maturity, early visibility of production rate problem, and reduced time from system conception to deployment (23:74). If concurrent programs consistently produced these types of benefits, most of the DOD acquisition problems would be eliminated.

As discussed earlier, not everyone agrees concurrency is the solution to our acquisition problems. Representative Smith, Co-chairman of the Military Reform Caucus commented, "concurrency isn't really needed unless we're in a real wartime situation" (37:46). At one time, Mr. Packard rejected the use of concurrency because it produced cost overruns, took too long to develop systems, and resulted in low reliability (40:3-4). A review of GAO reports also shows recommendations to limit or avoid the use of concurrency. GAO concluded that concurrency increases program risk, raises costs, results in lower performance, and provides inadequate test data for decisions (5:44; 21:4-5).

A 1983 study by Terence R. ST. Louis stated that prior to 1970 some concurrent acquisition programs failed because OT&E was performed after the system was in production. Consequently, operational deficiencies were not identified or corrected prior to production (49:13).

The debate over concurrency's use in DOD development programs is beginning to focus on a discussion of how much concurrency is really needed. The Defense Science Board, 1978, concluded that to be successful the right amount of concurrency should be used based on the level of program risk and the system urgency of need (7:51). Several criteria exist for determining a program's success. For a long time the criteria was limited to schedule, cost, and operational capability. However, recently additional considerations have been added to the determination of program success. A 1984 memorandum from Secretary of the Air Force Verne Orr and Chief of Staff Gen. Gabriel stated:

> For too long, the reliability and maintainability of our weapon systems have been secondary considerations in the acquisition process. It is time to change this practice and make reliability and maintainability primary considerations (29:1).

Reliability and Maintainability

R&M issues have been receiving increasing management attention for the past few years. As the cost and sophistication of Air Force weapon systems have increased, the need to improve system R&M has grown in importance (4:16). Reliability is the probability that an item will perform a required function under specified conditions for a specified period of time. Also expressed as the average time an item will perform a specified function without failure" (11:37; 53:E-14). The level of reliability obtained by a weapon system determines the importance of system maintainability (32:25). AFR 80-14 defines maintainability as "a measure of the time or maintenance resource needed to keep an item operating or restore it to operational (or serviceable, in the case of munitions) status" (11:35). According to Major Hodgson, DOD Directive 5000.40 defines maintainability as:

> That ability of an item to be retained in or restored to specified conditions when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources... (30:10).

The combination of system reliability and maintainability produces system inherent availability (32:25). Availability is the "probability that an item is in an operable state at a random point in time when used under stated conditions" (53:E-14).

The relationship of R&M to system availability and combat capability makes R&M important concepts in today's acquisition environment (53:E-21). An April 30, 1981 Deputy Secretary of Defense Memorandum to improve the acquisition process called for designed in R&M as a means to improve system readiness (4:62). General Mullins acknowledged reliability as the true measure of merit of a weapon system and the single most limiting factor in terms of accomplishment of wartime taskings (38:14). DOD has been involved in reliability improvement programs for many years.

Reliability History (39)

A paper titled "A Reliability Chronology" by Thomas A. Musson, C.P.L. provides a look at the emergence of reliability in system acquisition since the 1950s. Mr. Musson provides a short evolution of three aspects of the DOD reliability program. He focuses on the changing objective of reliability improvements, the management reviews and directives, and the search for a solution to reliability problems over the past three decades.

As pointed out in the article, the objectives of reliability activities have always been focused on a bigger issue facing the Department of Defense. The changes in improved reliability objectives resulted from either attainment of the objective or a change in the environment. Beginning in the 1950s emphasis was on increasing the operational time of equipment to keep it working. Next the focus moved to insure improved mission reliability. A tightening defense budget in the 1970s caused a shift to the cost reduction benefits of improved reliability. This fostered development of baselines and life cycle cost and logistic support cost analysis. A preoccupation with reducing costs caused a shift away from the ultimate goal of a weapon system which is to provide combat capability. In the past ten years, DOD and the Air Force have managed reliability improvement programs to balance system cost and readiness. Along with these objectives, improved reliability will reduce the quantity and skill levels of personnel required to maintain current and future weapon systems.

Mr. Musson identifies six significant events in the shaping of reliability programs. In 1952, the Advisory Group on Reliability of Electronic Equipment (AGREE) was established. AGREE was comprised of nine task groups which worked to improve electronic equipment reliability by developing programs in the areas of numerical reliability requirements, tests, design procedures, components, procurement, packaging and transportation, storage, and operation and maintenance. One requirement for improving reliability, identified by AGREE, resulted in the formation of the Ad Hoc Study Group on Parts Specification Management for Reliability. This group's report resulted in establishment of reliability military specifications for piece parts such as transistors and diodes. In the 1970s the Electronics-X Study by the Institute for Defense Analysis and the Joint Logistics Commanders Electronic Systems Reliability workshop provided the impetus towards the use of warranties and incentives to reduce cost and improve reliability. The most recent events identified in this article were the publishing of the DOD Directive on Reliability and Maintainability, 5000.40, and the Defense Acquisiton Improvement Program. These actions were taken to increase the overall efficiency and effectiveness of the reliability program and to focus attention on reliability as a design factor.

One of the reasons for so many management evaluations of DOD reliability activities was the search for a simple solution to insure that the desired level of reliability was obtained in the weapon systems. Many factors have resulted in DOD not reaching its reliability goals. These include the resources and commitment made towards the reliability effort, and the complexity and technical challenge associated with some particular items. Cost and the unwillingness to trade some system capability for reliability gains has also limited the overall results. Initially, the use of statistics and quantitative measures were considered the answer to improved reliability. From this ability to define and measure reliability, DOD focused on piece part specifications as the key to better systems. Testing and demonstration of specification compliance by the contractor also failed to produce the desired field reliability because the test environment did not duplicate the operational environment. DOD next focused on the use of Reliability Improvement Warranties (RIW). RIW has in some cases improved system reliability. The current solution is to focus on reliability as an inherent characteristic of design. Each of the identified solutions provide a means of insuring improved system reliability. None can stand alone and the proper mix during system acquisition and system life cycle will provide the highest reliability possible.

Improving Reliability

According to Captain Demarchi, Igor Bazovsky stated the best and cheapest reliability improvements are obtained during system design through tradeoffs in system performance (9:12). Reliability improvements will increase the price of new systems by 10 to 15 percent (44:44). However, this investment provides a force multiplier through increased sortie production and logistics sustainability which improves system availability and combat effectiveness (44:45; 53:E-14,E-21). By increasing system R&M, the Air Force can reduce the quantity and cost of support personnel, equipment, and spare parts (30:11; 53:E-13).

R&M improvements begin early in the acquisition cycle with better R&M specifications stated as contractual goals (53:E-13). In 1981 a design engineering emphasis panel identified the most cost effective reliability tasks as parts derating, parts selection and control, failure analysis and corrective action, parts screening, and burn-in (15:25).

> Derating is the practice of reducing the electrical, mechanical, or environmental operating stresses below the maximum levels the part is capable of sustaining ... resulting in an increased part lifetime (15:28).

> Burn-in is submitting deliverable end items to a short test, at the highest practical level of assembly, to disclose weak parts and manufacturing defects for correction prior to delivery (50:143).

Several DOD programs have been credited with achieving successful R&M standards. R&M improvements were obtained through design and system modifications after production start. The F-15 and F-16 aircraft are examples of improved R&M during the design process when compared to the F-4. The F-15 requires one third fewer manhours per flying hour and the F-16 requires only half the manhours per flying hour of the F-4 (17:10-11). The Army's Black Hawk helicopter proved that performance and reliability can be coproduced (34:39). According to General Russ, R&M modifications to the F-15 fleet since 1974 resulted in a 50 percent increase in missions per aircraft per month in 1985 (17:10). Other systems acknowledged as current R&M successes are the Navy's F-18 aircraft, the Army's M-1 tank and Firefinder Radar system, and the Air Force's F-16 APG-66 radar (34:39; 53:E-12,E-18).

Improved weapon system reliability will provide significant returns in supportability. These improvements can be obtained in three ways: early design, testing and redesign after production start, and through system maturity (34:39). By doubling the reliability of the F-16 avionics and engine subsystems, spare parts costs and manpower requirements could be reduced by 45 and 40 percent, respectively (27:83). Another example of increased savings from improved R&M was provided by General Mullins. Increasing a system reliability 25 percent from a mean time between failures (MTBF) of 500 hours to 625 hours, results in a 40 percent reduction in spares requirements while maintaining the same aircraft availability (38:16).

In 1972 David Packard identified one way to obtain system reliability build it, test it, and fix things that go wrong; then repeat until desired reliability is achieved (4:5-6). Today's test and evaluation policy is designed to discover system capabilities and limitations before a system is produced and deployed (49:11). The Acquisition Improvement Program established initiatives to provide adequate front end funding for test hardware to shorten acquisition time without increasing risks (18:6). These initiatives would allow for concurrent development and testing phases (3:11; 18:6).

> ...if high confidence is to be placed on reliability and support goals to be achieved in fielded defense systems, iterative design and testing must be conducted before full rate production (47:9).

An iterative test, analyze, and fix phase (TAAF) is an important element in producing reliable systems.

> TAAF is a technique for reliability development and growth testing that requires that a series of tests be conducted, problems identified and analyzed, and corrective actions taken. TAAF provides a means to accelerate design and reliability maturity by correcting identified design performance and reliability problems (41:12-13).

However, managers must be cautious in accepting design fixes without verification. Fixes may result in new system problems due to new failure types and other component interactions (32:26).

Problems in Reaching R&M Goals

Efforts to reduce costs and improve system reliability, maintainability, and availability have not been as successful as desired (8:A-13). The available literature provides numerous interrelated causes for the failure of some systems to reach R&M goals. During the system acquisition cycle, decisions which affect R&M may be driven by funding and schedule constraints resulting in reduced R&M (15:27). A weapon system's operational performance receives the attention of management and Congress. Good performance prevents funding cuts (34:38-39). The competition for limited resources results in intense congressional focus on acquisition programs. Congress has been reluctant to support the increased upfront costs required for R&M improvements (6:9; 34:39).

> ... deferring the near term costs of R&M testing and design improvements, due to program cost and schedule constraints, can result in significantly higher support costs over the extended system life cycle (30:11).

The USAF R&M Action Plan Development Team reported that attempts to reduce the acquisition cycle are often cited as the cause of reduced R&M so that cost, schedule, and performance improvements can be realized (53:20). Steps taken to shorten acquisition times may involve system production prior to completing development model testing. This results in the use of concurrency (47:9). A 1980 study by the Vought Corporation found that R&M advances were sometimes off-set by the addition of more equipment to improve weapon system performance and capability (33:4-5).

The determination of a system's R&M is accomplished through data collection during testing and again in field operation. In 1977 Major Richard Rose discussed the reliability problem with several former Air Force program managers. Many of these managers did not feel there was a reliability problem since most programs achieved contractual reliability goals (43:9-10). A 1979 GAO report which covered reviews of 21 major DOD systems indicated a reliability problem in acquisition. GAO found a few cases where systems either failed to reach reliability goals or showed a potential for reliability problems during system testing (21:3-4).

R&M goals are usually expressed as measures of central tendency MTBF for reliability and mean time to repair (MTTR) for maintainability (43:41; 53:E-11). These R&M measures are tracked throughout a system's acquisition cycle. Several different test phases are used to develop predictions of a system's field R&M.

> DT&E is that testing and evaluation used to measure progress, verify accomplishment of development objectives, and to determine if theories, techniques, and material are practible; and if systems or items under development are technically sound, reliable, safe, and satisfy specifications (11:34).

> OT&E is testing and evaluation conducted in as realistic an operational environment as possible to estimate the prospective system's military utility, operational effectiveness, and operational suitability. In addition OT&E provides information on

> organization, personnel requirements, doctrine, and tactics. Also, it may provide data to support or verify material in operating instructions, publications, and handbooks (11:36).
>
> IOT&E is the first phase of operational test and evaluation conducted on preproduction items, prototypes, or pilot production items and normally completed prior to the first major production decision (11:35).

Testing and evaluation (T&E) are key elements in determining the capabilities and limitations of systems. Despite the importance of T&E, its accomplishment is affected by limits of time, money, and resources resulting in the use of concurrent DT&E and IOT&E (49:33). Some critics of current acquisition programs feel that OT&E does not catch problems in time to keep them from going into production and at times data is fudged to prevent the surfacing of problems (5:41). Several studies have shown that "predicted reliability does not correlate well with field experience" (14:56; 15:26).

A 1977 study by Hughes Aircraft Company which examined 16 different types of avionics systems provided some explanations for the variances between predicted and field reliability. The findings showed that field reliability was sometimes dependent on the type of aircraft. Like equipment installed in subsonic bombers and transports exhibited 2 to 4 times higher reliability than when installed in fighters and trainers. Hughes personnel also found as much as a 5:1 difference in reliability based on weapon system location. This variance was attributed to differences in maintenance practices, manpower skill levels, and the geographic/

climatic environment (14:56). Additional hindrances to duplicating T&E R&M results, experienced by user command personnel, are problems in receiving test equipment and spare parts delayed due to system design changes (35:23-24; 54:61). Other factors which contribute to the poor accuracy of R&M predictions can be found in the T&E phase. They are:

> The use of contractor personnel to maintain systems. Contractor personnel are usually more skilled and experienced than user command technicians (19:32; 46:834). Inadequate test and support equipment used during T&E. The use of contractor equipment not available to field units (20:4,23; 46:834). Test articles were not representative of production article (20:10; 46:834). The establishment of a logistics system dedicated to testing which provided direct access to manufacturers for spare parts and expedited shipments (20:23).

The link between reliability and maintainability causes the problem of poor reliability predictions to be magnified in the field. Reliability data produced during T&E is used for maintainability predictions, spares provisioning, support equipment utilization, and manpower requirements (43:85). A RAND study of the A-7D aircraft demonstrated a significant difference between predicted and operational MTBFs. Five major avionic systems were evaluated with the radar showing the largest disparity, 250 hour predicted MTBF compared to an actual 25 hour MTBF (43:10-13,53-54). A review of the F-15 aircraft program in the early operational stage provided data showing poor maintainability predictions and that low reliable systems consumed high levels of maintenance time (43:20-21).

Anthony J. Feduccia, Systems Reliability and Engineering Branch Chief, listed six reasons for the difference between predicted and achieved reliability: false removals, definition of failure, maintenance induced failures, environment, configuration changes, and spare parts (15:26). A major contributor to the conflicting results of reliability analysis is based on the question of what constitutes a failure (32:27). During the system acquisition cycle representatives from the System Program Office (SPO), DT&E and OT&E test team, and sometimes the contractor form a Joint Reliability and Maintainability Evaluation Team (JRMET). The purpose of JRMET is to collect, analyze, and categorize R&M data during T&E (10:4). R&M measures are influenced by the team's definition of what failures will be counted in the R&M calculations. Several important definitional guidelines exist to make this determination.

> Non-relevant failures: only those failures that are caused by a condition external to the equipment under test that is not encountered in field service.
>
> Relevant failures: includes all failures incurred during test that can be expected to occur in the field.

Relevant failures are further subdivided.

> Chargeable failures: those relevant failures incurred during test which are caused by any of the goods or services provided by a given contractor.
>
> Non-chargeable failures: those relevant failures incurred during test which are caused by and are dependent upon a condition previously stipulated as not within the responsibility of a given contractor (50:131).

Only chargeable failures as determined by JRMET are used to make R&M calculations. This close scrutiny of failures during T&E is not duplicated in the field. This results in inconsistent R&M measurements. While T&E requirements do not count some failures, these non-chargeable failures have a significant impact on manpower, support and test equipment requirements, and spares provisioning. Examination of actual data from a fielded avionic system provides an insight into problems from failure definition differences. The contractor's reliability prediction was a 150 hour MTBF; however, the field showed an average of only 75 hours. The differences in MTBF values was due to the inclusion of failures by the field which included induced failures and maintenance actions such as; could not duplicate, retest-OK, bench check serviceable and adjustments. While these field counted failures are not considered chargeable failures during T&E, they do have a significant impact on maintenance of the system (15:26; 41:14). Besides the impact of MTBF differences on a fielded system's maintainability, the use of MTTR as a measure of maintainability presents problems. MTTR calculations do not include time to locate spares and test equipment, or downtime due to human or software errors. These occurrences produce as many problems for maintenance personnel as hardware failures (15:25). The continued slow progression of R&M improvements in Air Force weapon systems led to the establishment of the Air Force R&M 2000 program.

R&M 2000

The Air Force R&M 2000 Program was designed to mobilize senior level management interest in improving weapon system R&M and to institutionalize R&M concepts (46:44; 55:51). The basis for development of R&M 2000 was the perceived Soviet threat to European depots, airlift limitations, and the future expected shortfall in maintenance personnel (27:81,83; 44:44-45). This current R&M improvement program is also directed at DOD contractors and has the management support needed to minimize the trade-off of R&M requirements for cost, schedule, and performance (24:49; 53:E-11). The R&M 2000 Program involves both development and fielded systems and is supported by all major commands. The Air Force is serious about improving weapon system R&M as demonstrated by programs being delayed or cancelled for failure to meet R&M goals/requirements (25:16; 27:83,85). One Air Force source told Defense Electronics "this time, we're not just asking contractors to beef up reliability," ..."this time, it's an ultimatum" (27:81). By increasing system reliability and maintainability the Air Force will meet the goals of the R&M 2000 Action Plan:

Increase warfighting capability.

Increase survivability of the combat support structure.

Decrease mobility requirements per deploying unit.

Decrease manpower requirements per unit of output.

Decrease costs (41:1).

Summary

This chapter provided a review of the use of concurrency in the DOD acquisition process. The main reasons presented for concurrent acquisition programs are to reduce costs and development time. Some negative aspects identified with concurrency's use are that it results in lower performance, provides inadequate test data for program decisions, and reduces reliability. The current acquisition philosophy accepts the use of concurrency based on system need and program risk. Some level of concurrency appears to exist in all programs.

Also during this literature review, the researcher covered the areas of system R&M. Reliability and maintainability were defined. The increasing costs of new weapon systems has made R&M important aspects of system acquisition. While R&M has received increased management attention, the R&M measures of MTBF and MTTR have failed to reach desired field levels. This results in reduced weapon system capability and availability. A few of the reasons for R&M problems can be found in the structure of T&E phases and in the calculations of R&M measures. The next chapter will provide the methodology used in this thesis to determine concurrency's impact on R&M and acquisition personnel views on the use of concurrency.

III. Research Methodology

Data Collection

A literature review was conducted to find historical examples of the use of concurrency in system acquisitions. During this review, the researcher concentrated on investigating the reasons that concurrency has been identified as having both a positive and negative impact on the acquisition process. The researcher examined the literature and obtained a perspective on weapon system R&M. This review focused on reporting the benefits and hindrances to R&M improvements. The researcher found several references which identified some problems with the quantitative measurements of R&M developed during T&E in accurately predicting system field performance.

A qualitative determination of the impact of concurrency on acquisition and system R&M was obtained through interviews of managers actively involved in the acquisition process. The personnel interviewed were assigned to the following organizations/offices: AFSC/System Program Office (SPO), AFLC/Deputy Program Manager for Logistics (DPML), and AFOTEC/Operational Test Team. The researcher chose these organizations/offices to obtain a comparative data base on concurrency. Based on the manager's position and experience with concurrency's affect on acquisition and R&M, different responses could result when compared to other program areas.

Procedure

To determine the programs in which to conduct interviews, the researcher spoke with the Deputies in the Acquisition Divisions located at Wright-Patterson AFB. The person contacted in each Acquisition Division provided a number of programs which would meet the program selection criteria. Acquisition programs selected for inclusion in this thesis used concurrency and were close to or past the production decision. After a program was identified to be used in this study, the personnel selected for the interviews were determined by the cluster sample technique. In the cluster sample technique, "...the entire population is divided into groups of elements and some of the groups for study are randomly selected" (13:312). For this thesis the population, all acquisition personnel, was divided into groups, a specific weapon system program. After a program was identified as meeting the thesis selection criteria, the interviewees were chosen. Five acquisition programs were used in this thesis and personnel assigned to the SPO, DPML, and AFOTEC areas in each program were interviewed. The listing of the interviewees can be found in Appendix A.

Interviews were chosen as the means tó collect the data for this thesis because the use and definition of concurrency varies. Also, the definition of R&M and its quantitative measures vary. During interviews the researcher was able to account for these differences. Interviews of SPO and DPML personnel were arranged and conducted in person at Wright-Patterson AFB. These interviews were taped to insure accuracy. However, interviews of AFOTEC personnel were conducted over the phone and required manual recording of the responses. When appropriate, a transcript of the interviews has been provided in Appendixes B to H. In some cases the interviewees were not able to respond to all the interview questions. To ensure non-attribution, the interviewees were assigned a random number. This number was used to consistently identify a particular individual's responses without identifying the individual. Also, all references to the specific program were removed from the transcripts.

Interview Questions Development

The interview questions were designed to answer the investigative questions in terms of factors which influence the acquisition process, specifically in the areas of R&M. The factors used were determined through a review of the literature (15:25-26; 20:4,10,23; 21:8,10). Interview questions 7 through 14 are based on these factors. The interview questions are listed below:

1. What is your general assessment of the use of concurrency in acquisition?

2. What phase of the acquisition process is your program currently in?

3. What was the original risk assessment of your program?

4. Was the use of concurrency planned from the beginning of your program?

5. If concurrency was not originally planned, why was it later incorporated and in what phase of acquisition?

6. What phases of your program were concurrent?

7. Who was responsible for the maintenance of your system during DT&E and IOT&E and at what level? (organizational, intermediate, depot) If the contractor, does this bias the R&M data?

8. What was the status of the system unique support equipment during DT&E and IOT&E?

9. What was the status of the system unique test equipment during DT&E and IOT&E?

10. What was the status of technical data during DT&E and IOT&E?

11. Did concurrency cause a delay in DT&E to complete IOT&E in order to meet a production decision date? What problems did this cause?

12. Did concurrency result in a design freeze earlier than planned?

13. Were there open engineering change proposals (ECP) dealing with R&M issues at the time of IOT&E? Will these changes result in a significant design difference between the tested and production articles?

14. Did concurrency reduce your ability to use a test, analyze, and fix procedure to identify potential reliability problems?

15. How does concurrency benefit R&M?

16. What are the primary benefits of a concurrent program?

17. What problems are associated with a concurrent program?

18. What needs to be done to improve system R&M during acquisition?

19. What do you feel accounts for the differences in R&M measures between DT&E, IOT&E, and field results?

Data Analysis

The initial results of this research provided a background of concurrency and identified the reported benefits and problems. The researcher compiled published data on the adequacy of R&M test data in predicting system field data. Answers to Questions 2 through 6 were used to compare the programs in this study and are not included in an appendix but are summarized in the findings chapter. Managers' opinions on the use of concurrency were documented through the remaining questions. A statistical analysis was conducted on the responses to interview questions 7 through 14 using descriptive statistics based on the answers to the hypotheses listed in the next section. The data was evaluated in terms of frequency and count of the individual manager's responses.

Hypotheses

A hypothesis was developed for each interview question (7-14) to ascertain the manager's opinion of factors which may impact reliability and maintainability when comparing DT&E/IOT&E results to the operational field reported R&M. Each interviewed individual's answer was recorded. However, some interviewees could not respond to all the questions presented. The hypotheses developed for this evaluation are:

1. Use of contractor personnel for system maintenance reduces the accuracy of system R&M measures. (Ques. 7)

2. Lack of system unique support equipment during testing reduces the accuracy of system R&M measures. (Ques. 8)

3. Lack of system unique test equipment during testing reduces the accuracy of system R&M measures. (Ques. 9)

4. The lack of system technical data during DT&E and IOT&E reduces the accuracy of system R&M measures. (Ques. 10)

5. Incomplete DT&E and IOT&E testing prior to the production decision reduces the accuracy of system R&M measures. (Ques. 11)

6. Early system design freeze for IOT&E will reduce the accuracy of system R&M measures. (Ques. 12)

7. Open/untested ECPs at the time of production decision reduces the accuracy of system R&M measures. (Ques. 13)

8. An incomplete test, analyze, and fix program during development reduces the accuracy of system R&M measures. (Ques. 14)

An example of the method used to categorize the interview data follows in Table 1.

Table 1

Hypothesis 7 Interview Question 13
Example

Hypothesis: Open/untested ECPs for reliability improvements at the time of the production decision reduces the accuracy of system R&M measures.

		Did open/untested ECP reliability improvements exist at the time of the production decision?	
		YES	NO
Reduces accuracy of system R&M measures	YES	X	
	NO		

In this example the interviewee stated that open ECPs did exist at the time of the production decision and that this did/or will result in lower field R&M measures.

Limitations

The factors identified as having an impact on system reliability and maintainability cannot be empirically demonstrated.

Only Air Force acquisition programs which had already experienced a production decision were used to select personnel to be interviewed. This selection criteria resulted in a small data base with limited generalization capability.

Summary

Part of the data base for this thesis was developed through a literature review of concurrency and R&M material. Data collection was directed at determining the relationship between concurrency and weapon system R&M. The researcher also extracted data from the literature which provided a set of factors identified as impacting weapon system R&M. The remaining data base was obtained through interviews with acquisition personnel. These interviews provided the information used to determine the impact of concurrency on acquisition. Interview questions were also developed to determine the manager's opinion on whether or not the factors which may affect R&M had an impact on their program.

IV. Findings

Introduction

This research effort used two methods to develop a data base. The data collection was initiated with a literature review to obtain information on concurrency's use in weapon system acquisition. This information was then used to develop interview questions for the purpose of obtaining the opinions of managers involved in the acquisition process. This chapter provides findings to answer the thesis research questions presented in Chapter I and is divided into two sections literature review findings and interview findings.

Literature Review Findings

Weapon System Programs Successfully Developed Using Concurrency. The Department of Defense began using concurrency with the advent of the Ballistic Missile Program. This highly concurrent program was initiated to develop an ICBM before the Russians. The Ballistic Missile Program was the number one national priority during its acquisition and successfully developed three versions: Atlas, Titan, and Thor. More recently developed missile programs classified successful by the 1977 Defense Science Board Task Force were the Polaris and Minuteman. The Task Force also identified the F-5E aircraft as a highly concurrent program which met cost, schedule, and performance objectives. The U-2 and SR-71 aircraft developed by Lockheed have proven to be very effective weapon systems. Also two of the Air Force's modern fighters the F-15 and F-16 C/D can be classified as successful programs which used some level of concurrency. While these weapon systems prove that concurrency's use in acquisition can produce systems which meet military needs, concurrency has not been totally accepted.

Concurrency Has Been Periodically Accepted and Rejected. Over the years the results of concurrent acquisition programs have ranged from unqualified success to total failure. Following the development of the ICBMs and the U-2 and SR-71 aircraft, concurrency was an accepted acquisition process. These programs were acquired using concurrency as a management philosophy and there are several reasons which account for their success. Concurrency was planned from the beginning of the programs. Program management was given almost complete autonomy with the required overall responsibility and authority for all aspects of the program. This enabled management decisions to be made at the lowest level possible. The program staff consisted of a small group of highly qualified and skilled personnel. To overcome the high risk of the new and advanced technology required to produce the ICBM, competition was extensively used during development. The ICBM program received support from the highest levels of the military and civilian leadership as a national priority and did not appear to have any funding problems. Because there was very limited access to the project and its progress, program management was able to concentrate on managing the program instead of spending time justifying its continuation.

The first programs that indicated problems with concurrent acquisition were the early cruise missile programs. The management philosophies incorporated in the cruise missile programs were significantly different from the ICBM program. Concurrency was not initially planned, but was incorporated due to unplanned schedule compression. Also program managers' autonomy, responsibility, and authority was limited; therefore, reducing their ability to quickly deal with problems. As competition for limited national resources increased, DOD moved to an acquisition policy called Total Package Procurement.

Total Package Procurement (TPP) required a government commitment to production at the time of contract award and was concurrent. TPP limited the use of competition during acquisition and increased the centralization of authority and management layers in the acquisition process. Many systems developed under TPP experienced cost and performance problems. The MBT-70 and F-111B programs were cancelled while the C-5A and F-111 were continued to production.

In the 1970s Deputy Secretary of Defense David Packard rejected the use of concurrency and required the use of system prototypes and a sequential acquisition process. The use of system prototypes has led to the production of some very good systems such as the F-16, A-10, and the avionics and cannon subsystems of the F-15. Despite some improvements in the areas of program management and system testing, a lengthening acquisition cycle and increasing program costs resulted in continued evaluation of the acquisition cycle.

Our present day acquisition policy accepts the use of concurrency coupled with system prototyping when appropriate. The amount of concurrency and/or the decision to use prototypes depends on the level of technical risk and the national urgency of system need. Examples of programs using concurrency and prototyping are the B-1B, F-16 C/D, LANTIRN, and AMRAAM.

Benefits of Using Concurrency. The primary benefit of a concurrent acquisition program was demonstrated by the ICBM development. The ICBM program was expected to take from 10-11 years to complete; however, deployment and operational status was achieved within five years. The 1978 Defense Science Board reported benefits in savings in total acquisition costs and a longer useful system operational life before obsolesence. Concurrency can also provide early system design maturity and identification of potential production problems. The use of concurrency does not guarantee success and program managers must guard against potential problems.

Problems Associated With Concurrency. Concurrency increases program risks. In the overall evaluation concurrency has been blamed for causing the same problems it is credited with eliminating. Due to concurrency's shortened acquisition cycle, some programs have produced schedule slippages and increased costs. Therefore, the concurrent programs took too long to develop and had cost overruns. GAO reports have identified additional problems as inadequate test data for production decisions, poor system performance, and systems deployed with known problems requiring system design and retrofit. Also, concurrency has been identified as a cause of poor/low system reliability.

Testing R&M Indicators Versus Field R&M. R&M issues have received increasing management attention over the past few years. As the cost and sophistication of weapon systems have increased, the need to improve system R&M has grown in importance. Today acquisition directives require that R&M be considered equivalent to system performance. Therefore, system R&M must be tested and evaluated during the acquisition process. The available literature indicates that problems exist in reaching weapon system R&M goals. A 1977 Hughes Aircraft Company study of 16 different avionics systems showed variances between predicted and field reliability. A RAND study of the A-7D also demonstrated significant differences between predicted and field reliability. A review of the F-15 program showed early operational problems with R&M. Several probable causes for the disparity between R&M measures are provided in the literature. The reasons for low and inconsistent system R&M can be found throughout the management levels of the acquisition process.

During the acquisition process numerous program decisions are made which can impact R&M. These decisions are usually driven by funding and schedule constraints which may cause a negative impact on R&M. System R&M improvements can appear very costly when viewed in the short term development cycle. Current experience shows a lack of congressional support to provide the upfront funding required for R&M improvements. Also, congressional and senior management attention has placed system performance as the primary element in determining program continuation and funding. This mindset has placed R&M needs behind performance needs during development. Another issue which affects R&M and must be dealt with by senior Air Force leadership is in the calculation of R&M measures. Although guidelines are provided for these calculations, the definitions used to determine what constitutes a failure are different between DT&E, IOT&E, and the field. Therefore, there is little correlation between the R&M measures. Attempts to reduce the length of the acquisition cycle create additional problems which can cause a reduction in field R&M measures when compared to the predicted values. Consequently, concurrency has been considered a contributing factor to poor R&M. A compressed acquisition schedule may result in insufficient system testing which does not identify system problems in time to fix them and/or does not allow time to retest fixes to prove problems have been corrected before production. Other elements which affect R&M are the use of contractor personnel and support/test equipment during DT&E and IOT&E. The Hughes study showed that environmental differences and the type of aircraft in which a system is installed can affect system R&M. During system acquisition it is important for managers to consider all these areas with the potential to negatively impact R&M. The next section provides managers' responses outlining concurrency's impact on their program.

Interview Findings

Program Specifics. Interview questions 2-6 were developed to provide data on the programs used in this thesis. This data was needed to ensure concurrency's use and the current acquisition phase of each program.

Four programs included concurrency in the initial planning. The remaining program incorporated concurrency because of a firm IOC date and schedule slips due to technical problems and budget cuts. According to the interviewees, only one program was considered high risk at the start of acquisition. The managers interviewed reported that their programs overlapped during the full scale development and production phases. All programs used or are scheduled to use a combined DT&E and IOT&E testing procedure which in three out of five cases led initially to low rate production. Full rate production was later authorized after additional testing and development. All programs are presently engaged in some development and production.

Concurrency's Affect on Acquisition. Interview questions 1, 16, and 17 were used to provide information on the acquisition managers' general opinions of concurrency. Many of the managers interviewed stated that in today's acquisition environment concurrency is a necessity. One manager replied "It's almost mandatory that you have some level of concurrency with zero concurrency you would never get anything done." The literature recommends that to be successful, concurrency should be planned from the beginning of a program. Therefore, the decision whether or not to use concurrency should be made as early in the acquisition cycle as possible. This decision should be based on certain program characteristics. The program characteristics presented by the managers which support the goals of a concurrent program are:

1. A modification of an old system or a new system that is not a new state of the art technology.

2. System uses rapidly changing technology and must be deployed quickly to prevent obsolescence.

3. Program is low risk and/or uses proven technology.

4. Program urgency of need is high enough to justify the increased risk of concurrency.

5. High risk/new technology programs should not use concurrency.

To many of the managers interviewed, concurrency is neither good or bad. Its value is dependent on the system and the outcome of the program. For some the success of a concurrent program, "... depends on the quality of management in the SPO" and "... the proper cooperation between the developers and testers". The bottom line on concurrency was best summarized by one manager:

> I think it is necessary. It has some disadvantages but I also think it has some advantages. It's about the only way in the real world that you can do it [acquisition]. You don't have any choice you use it to stay in some sort of budget and schedule. You might start out with no concurrency but before you know it you will have concurrency.

Concurrency offers some benefits to acquisition programs.

Benefits. The primary benefit of concurrency identified by 86 percent of the interviewees was a shorter acquisition schedule. Several managers provided secondary benefits that are derived from quicker system deployment. These benefits are:

1. Lower acquisition costs.
2. Reduces the chance of program cancellation.
3. Provides a longer system useful life.
4. Makes it easier to get funding and avoid political turmoil.

One manager felt that concurrency could minimize the affects of some problems on the overall program.

> Concurrency allows you to meet a schedule. If you have problems in development and I'm not saying development problems, but in our case funding problems that cause you to stretch out development, ... you can still meet the end item schedule, IOC.

Two managers considered earlier involvement of user and operational personnel as an important aspect of concurrent programs, "It is important in that it provides the ability to identify operational problems early". Besides benefits concurrency's use results in increased program risk.

Problems. The potential for problems in concurrent programs was expressed by one of the interviewees, "Concurrency provides a shorter schedule ... You can always go back and fix it once you have it". While a shorter acquisition cycle is considered a benefit, it is also a source of several potential problems during concurrency. Less time to develop a system may translate into a shorter testing phase which creates problems as DT&E and IOT&E may or may not be completed prior to the production start. Two major logistics areas are impacted by this timing problem. As one manager stated:

> We're constantly slightly late getting the right configuration of support and test equipment out to meet the system and that is hampered by concurrency because we're just barely finishing up development before we start production.

Some additional areas of concern pointed out by the managers were:

1. Final item design may not be completed before production.

2. Systems may be delivered with some equipment not available.

3. Limits ability to complete R&M testing and incorporate fixes before production.

4. Fixes designed to correct problems found in DT&E and IOT&E may not be retested before production.

A further review of the interview responses indicated the need for system retrofits as the most reported problem. According to one manager, "Mostly, you'll find things that just don't work. It will be mandatory to go back and retrofit sometimes". Another manager provided this comment:

> You buy some problems with concurrency. Things will get out of sync and you'll be producing hardware and not be able to get all the changes into it [system].

The problem of system retrofit was a major concern of the SPO personnel interviewed. This concern with system retrofit is understandable since the SPO has overall system responsibility.

Concurrency creates problems for program management with many simultaneous activities requiring management attention. These include development and reliability testing, flight and ground testing for DT&E and IOT&E, R&M testing, and system integration. Many of these tasks impact the accomplishment of AFOTEC's mission. Consequently, AFOTEC personnel identified management of concurrent issues as a problem when an acquisition program has limited assets.

If acquisition managers fail to eliminate or minimize the potential problems of concurrency, the affects on a weapon system can be serious. An acquisition manager explained:

> ... an unstable configuration ... a lot of changes ... some of those can be costly ... you have more ECPs and the program is a little more turbulent. ... you could end up with a design that could not do the job either from a performance or R&M standpoint.

The primary goal of concurrency, a shorter schedule, is reportedly incompatible with the goal of improving system R&M. Therefore, the researcher developed several interview questions to evaluate concurrency's impact on R&M.

Concurrency's Impact On System R&M. Since most of the available literature did not provide positive R&M benefits of concurrent programs, the managers were asked to comment on this area through interview question 15. To obtain information on the reported factors which may negatively impact system R&M, interview questions 7-14 and hypotheses 1-8 were developed.

When asked to provide information on how concurrency benefits R&M, only four managers gave a positive response. Three of them identified the early involvement of user and operational personnel to evaluate the system as a benefit. Two other managers although they did not feel concurrency benefited R&M did provide some possible benefits.

> Maybe through schedule savings or savings in money so you can do other things you might want to do.

> ... one possible way, that while the guys are producing it the people in development, have a closed feedback between the two and they can make corrections.

While 10 of the 15 managers interviewed stated that concurrency did not benefit R&M, one manager's response seemed to summarize the groups' thoughts on this issue. He stated, "In concurrency you do things to benefit cost and schedule, the problems that arise are usually R&M".

Over the last several years one of the major issues of DOD acquisition programs has been to improve weapon system R&M. Numerous factors have been identified as causing the poor correlation between R&M measures reported for DT&E/IOT&E and the actual field demonstrated R&M of many weapon systems and subsystems. Several of these factors were reviewed in Chapter II and will be investigated further in the remainder of this chapter.

Contractor Personnel. All the acquisition programs used in this thesis utilized contractor personnel to maintain their systems during the FSD phase. However, four of the programs also used Air Force maintenance personnel. When asked if the use of contractor maintenance during DT&E/IOT&E caused a reduction in field R&M measures, nine managers (60 percent) said it did (see Table 2).

The responses to Hypothesis 1 appear to support the literature which states that the use of contractor personnel may negatively impact R&M. However, the managers felt that any bias of R&M data was minimal. The dominant reason given for the R&M bias was the skill and experience differences between the contractor personnel and the user command maintenance technicians. As one manager put it:

> The contractor has to bias it a little because he has highly qualified people compared to the average

> GI. He most likely has higher paid more experienced people and that would make the reliability and maintainability picture a little brighter.

Table 2

Hypothesis 1 Interview Question 7

Hypothesis: Use of contractor maintenance personnel for system maintenance reduces the accuracy of system R&M measures.

		Was contractor maintenance used during DT&E and IOT&E?	
		YES	NO
Reduces accuracy of system R&M measures	YES	9	
	NO	6	

According to another manager contractor maintenance primarily affected system maintainability.

> Your going to have a failure regardless of who fixes it, but then you might not necessarily see some of the problems with your support equipment or ... training. Your equipment will get fixed quicker than in the real world.

The impact to system R&M of this factor will be eliminated as Air Force personnel acquire experience explained one SPO. An analysis of the six managers who reported no bias showed that two were involved with a program which exceeded DT&E and IOT&E R&M in the field. Also, four of the five DPML personnel interviewed did not consider contractor maintenance a problem. All five AFOTEC personnel reported that the use of contractor personnel will impact R&M.

Support Equipment. Many acquisition programs do not have fully developed support equipment available during FSD and this may impact system R&M. Hypothesis 2 was designed to determine the support equipment status on the programs. Review of the responses showed that in four programs all three managers agreed on the question of equipment availability during DT&E and IOT&E. However, only one program had all managers report the same impact to R&M. On this program all managers felt that the nonavailability of support equipment would reduce field R&M. One manager did not respond to this question (see Table 3).

Table 3

Hypothesis 2 Interview Question 8

Hypothesis: Lack of system unique support equipment during testing reduces the accuracy of system R&M measures.

		Was system unique support equipment available during DT&E and IOT&E?	
		YES	NO
Reduces accuracy of system R&M measures	YES	1	6
	NO	3	4

Three programs were identified as not having the field projected support equipment; however, the managers disagreed on the impact to R&M. With 10 managers reporting a lack of equipment 60 percent felt it would reduce field R&M. The responses to this hypothesis were balanced between all management areas. The managers stated that either contractor or some type of modified equipment was used.

Test Equipment. As weapon systems become more integrated, the dependence on software increases. This trend results in the simultaneous development of both software and hardware for the weapon system and the test equipment. The reduced acquisition time of a concurrent program will increase the probability that test equipment will not be fully developed for use in DT&E/IOT&E. The lack of field test equipment has been identified as having a negative impact on R&M correlation between the testing and operational environments. Hypothesis 3 was designed to investigate this issue (see Table 4). One manager did not respond to the question.

Table 4

Hypothesis 3 Interview Question 9

Hypothesis: Lack of system unique test equipment during testing reduces the accuracy of system R&M measures.

		Was system unique test equipment available during DT&E/IOT&E?	
		YES	NO
Reduces accuracy of system R&M measures	YES	1	6
	NO	3	4

The managers in three programs did not agree on the availability of test equipment during their program's DT&E and IOT&E. There were no programs where all three managers agreed on the impact of test equipment on R&M measures. Ten managers acknowledged that the field system unique test equipment was not available during system testing. While 60 percent reported this would have a negative impact. In this group three of four DPMLs did not feel it would negatively impact R&M while the three AFOTEC personnel felt the lack of test equipment would result in lower R&M. Seven managers' response to Hypothesis 2 matched their response to this issue.

Tech Data. The lack of technical data during weapon system testing may impact system R&M. Technical data development, like test equipment, is affected by concurrency and the level of software in a weapon system. Hypothesis 4 deals with the availability of tech data during DT&E/IOT&E. Two managers did not answer this question. In four programs the managers responding agreed on the availability of tech data during testing. However, only two sets of managers agreed on the impact to their system. In one case tech data was available with no impact to R&M. While the other program reported no tech data and the managers felt this would reduce R&M measures. Eight managers reported a lack of tech data during their program testing but only four, three from AFOTEC, considered it a problem for R&M. Also, in two cases both the SPO and DPML reported no impact while their AFOTEC counterpart felt R&M would be reduced in the field. In the opinion of one SPO the lack of tech data during testing coupled with its availability later in the field would have a positive affect on field R&M measures (see Table 5).

Table 5

Hypothesis 4 Interview Question 10

Hypothesis: The lack of system technical data during DT&E and IOT&E reduces the accuracy of system R&M measures.

		Was tech data available during DT&E/IOT&E?	
		YES	NO
Reduces accuracy of system R&M measures	YES		4
	NO	5	4

<u>Incomplete</u> <u>DT&E/IOT&E</u>. Several studies have indicated that concurrent programs produce incomplete testing, may delay DT&E to complete IOT&E, and/or fail to identify system problems before production. Data was collected to determine whether or not the five concurrent programs used in this study experienced any of these problems. All programs used a combined DT&E/IOT&E phase that is that some DT&E and IOT&E testing was being accomplished at the same time. As a group the managers did not feel that DT&E was

delayed to complete IOT&E. According to one manager in his program IOT&E had been delayed for DT&E. Other managers reported finding problems which caused a delay in the full rate production decision. Hypothesis 5 was designed to see if production decisions were made with incomplete DT&E/IOT&E. In response to this hypothesis the three managers in four programs all agreed to the status of DT&E/IOT&E at the time of their program's production decision. In two cases the managers agreed on the impact to R&M. Analysis of the responses to this hypothesis shows eight managers in programs where a production decision was made before completion of DT&E/IOT&E with 88 percent reporting a reduction in field R&M measures. The remaining seven managers felt DT&E/IOT&E were completed before the production decision and 85 percent reported that this would not reduce field R&M (see Table 6).

Table 6

Hypothesis 5 Interview Question 11

Hypothesis: Incomplete DT&E and IOT&E testing prior to the production decision reduces the accuracy of system R&M measures.

		Was production decision made with incomplete DT&E/IOT&E?	
		YES	NO
Reduces accuracy of system R&M measures	YES	7	1
	NO	1	6

Design Freeze. According to the literature, an early design freeze will negatively impact the relationship between testing and field R&M. Interview question 12 and Hypothesis 6 were developed to look at this area. In response to the issue of design freezes 67 percent of the managers did not think that concurrency caused an early freeze. Several managers reported that their programs have continued to have design changes with some occurring up to and surpassing the start of production. One manager said:

> The design has undergone several refinements, some performance related as a result of original testing phases. Other significant changes were done for reasons of cost and manufacturing effectiveness.

Expressing a different idea one manager explained that concurrency prevented a design freeze until after production. This resulted in retrofits to some production items. The remaining five managers considered concurrency as a cause of early design freezes and their thoughts are reflected in this manager's comments:

> ... after the design freeze your still finding problems which if they prove significant may result in retrofits. ... some unquantifiable long term effect on R&M because you could not get some changes in that you would like.

Only 13 managers were sure about their program's use of a design freeze. The results of the responses showed four programs where the managers agreed on whether or not the system experienced a design freeze. However, the managers of only two programs concurred on the impact of this action. Table 7 provides the data collected for Hypothesis 6.

Table 7

Hypothesis 6 Interview Question 11

Hypothesis: Early system design freeze for IOT&E will reduce the accuracy of system R&M measures.

		Was there an early design freeze to complete IOT&E testing for the production decision?	
		YES	NO
Reduces accuracy of system R&M measures	YES	1	2
	NO	5	5

Overall 77 percent of the responding interviewees did not feel that having or not having a design freeze for IOT&E would result in any problem for field R&M measures. This result supports the data collected for interview question 12 and disagrees with the available literature.

Engineering Change Proposals. Interview question 13 and Hypothesis 7 looked at the potential impact of open/untested ECPs on system R&M. Some managers were unsure of the status of ECPs at the time of IOT&E and the production decision and did not answer. The other managers indicated that it is normal practice to have open/untested ECPs going into both IOT&E and the production decision. The ECPs were not only for reliability issues but also dealt with performance, producibility, and maintainability. A few managers pointed out that their program had some ECPs dealing with support/test equipment. The ECPs were usually a result of problems found in DT&E that were not corrected in time for IOT&E. On one program many of the ECPs were not going to be fully implemented until production (see Table 8).

Table 8

Hypothesis 7 Interview Question 13

Hypothesis: Open/untested ECPs for reliability improvements at the time of production decision reduces the accuracy of system R&M measures.

		Did open/untested ECP reliability improvements exist at the time of the production decision? YES	NO
Reduces accuracy of system R&M measures	YES	5	
	NO	4	2

Of the 11 managers who responded to the hypothesis, 82 percent reported a production decision with open/untested ECPs. However, only 56 percent felt this would result in reduced R&M measures in the field. When looking at the data to see if the individual program managers agreed, only two programs existed with all managers agreeing on the status of ECPs. There were no programs where all managers reported the same impact. Further review showed that an individual's response was influenced by his area of responsibility. All three AFOTEC respondents thought open/untested ECPs reduced field R&M measures.

Test, Analyze, and Fix. The literature proposes the use of TAAF as a very important means of developing reliability improvements and indicates that concurrency may reduce its use. Interview question 14 and Hypothesis 8 are presented in this thesis to investigate this issue. During the interviews one manager did not feel his program used a TAAF phase and two others were not sure how complete their program's testing was during development. Therefore, these managers did not answer the questions. Analyzing the responses to the question of whether or not concurrency impacted their TAAF phase showed that 64 percent of the managers did not see concurrency as a problem. The comments of one manager seemed to explain the use of a TAAF phase in a concurrent program:

> ... what your going to find is we're out there flying equipment while we're still in the lab doing reliability growth programs. So we're still using it but it's just a concurrent phase. We have lab testing going on at the same time we have operational testing going on.

This statement also provides a look at the general response for the managers who reported that concurrency does impact a TAAF program. The impact was experienced in the amount of time to perform the TAAF phase. As one manager stated, "There were some technical problems experienced and this resulted in ... maturity problems. Some fixes had to be checked in IOT&E". Several managers expressed the opinion that a TAAF phase was a very cost effective means of finding system problems. There were other issues presented by the managers that can impact a TAAF program. These include: limited test assets, a reluctance to fix identified problems due to cost, and the potential of a program being cancelled because of system failures during the TAAF phase. Of the five programs used in this thesis three sets of acquisition managers agreed on the status of TAAF during development and TAAF's impact on their program. In all three cases the programs had an incomplete TAAF phase during development and the managers felt this would reduce the R&M measures in the field. This response supports the researcher's findings in the literature. Looking at the managers' answers to the hypothesis shows that 67 percent reported an incomplete TAAF phase in development with 88 percent indicating this will have a negative impact on R&M (see Table 9).

Table 9

Hypothesis 8 Interview Question 14

Hypothesis: An incomplete test, analyze, and fix program during development reduces the accuracy of system R&M measures.

		Was there an incomplete test, analyze, and fix during development?	
		YES	NO
Reduces accuracy of system R&M measures	YES	7	1
	NO	1	3

Program Results. One of the main intents of this research was to determine the extent that the factors identified in the literature influenced concurrent programs in the area of R&M. A secondary goal was to see if acquisition managers in the same program but from different major areas of concern for system development had similar opinions of their program.

An analysis of the acquisition managers' responses was conducted to determine the applicability and impact on R&M of the hypothesis factors from a program standpoint. The factors were:

1. Contractor maintenance used during DT&E/IOT&E.
2. Lack of system unique support equipment during testing.
3. Lack of system unique test equipment during testing.
4. Lack of system technical data during DT&E/IOT&E.
5. Incomplete DT&E/IOT&E prior to production decision.
6. Early system design freeze for IOT&E.
7. Open/untested ECPs at the time of production decision.
8. Incomplete TAAF phase during development.

In order to accomplish this analysis, the researcher had to make some assumptions about the recorded data. Most interviewees had at least one to three years on their program with only two having less than six months. Some acquisition managers could not answer all the hypothesis questions in terms of their program. The fact that current acquisition programs take from 10-12 years and personnel turnover accounts for some of this data loss. Another issue requiring adjustment was identified when looking at manager concurrence on the factor's status and impact on the individual programs. With eight hypotheses presented in five programs, a total of 40 answers could have reflected the concurrence of three managers. However, the answers to the hypotheses showed that three managers agreed only four times when the responses for all five programs were totaled. Further analysis showed that a total of 30 times at least two managers provided the same response. While the disparity between the potential responses and the actual responses can be somewhat explained by the 13 times managers did not reply to the hypotheses, it does not explain it all. In order to evaluate the factors in terms of each program the researcher used the hypothesis response provided by at least two of the three managers to represent the program. If at least two common responses could not be found in terms of factor status and/or impact on R&M, the program was not counted in the results. Therefore, the analysis of some factors will show less than five programs.

Contractor Personnel. All five acquisition programs used contractor maintenance. In four programs at least two of the three managers felt it would reduce the accuracy of R&M measures in the field when compared to test results. The other managers felt there was no R&M impact.

Support Equipment. Four programs were evaluated for this issue. In three programs system unique support equipment was not available during testing. The managers in two programs reported that this would impact R&M and one program's managers expected no impact. In one program the support equipment was available.

Test Equipment. Of the four programs used to provide data on this factor, three confirmed that system unique test equipment was not available during testing and that this would negatively impact system R&M. Test equipment was available in the fourth program.

Tech Data. Three of five programs did not have tech data during testing. Management in two of these programs felt the lack of tech data would not impact R&M. Only one program reported that a lack of tech data would reduce R&M measures' accuracy. Tech data was available during testing in one program.

DT&E/IOT&E. The management responses showed that in three programs the production decision was made with incomplete DT&E/IOT&E and this would reduce the accuracy of R&M measures. Two programs were able to complete DT&E/IOT&E requirements before the production decision.

Design Freeze. The data showed three programs did not have a design freeze for IOT&E. Two programs did have a design freeze. In two programs the impact of this factor could not be determined. The other program managers did not feel this factor would affect R&M.

ECPs. Three programs did have open/untested ECPs at the time of the production decision with one reporting no impact to R&M. Due to the disparity of the managers' answers, two programs were not counted at all and the impact on R&M for two programs could not be determined.

TAAF. The data on three programs showed that there was an incomplete TAAF phase during development. The managers felt that it would result in reduced R&M field measures. The remaining two programs were able to complete their TAAF programs.

This review of the data collected in response to the eight hypothesis questions showed that all but one of the hypothesis conditions were present in at least three of the five programs. The factor of a design freeze for IOT&E was only used in two programs. Three of five programs supported the thesis hypotheses dealing with the factors of test equipment, incomplete DT&E/IOT&E, and incomplete TAAF. The hypothesis covering the use of contractor maintenance was confirmed in four of the five programs.

Managers' Opinions on the Difference Between DT&E/ IOT&E and Field R&M Measures. The hypotheses developed in this thesis did not cover all the reasons for the difference between testing and field R&M results identified in the literature. Therefore, interview question 19 was included to obtain additional data on this issue.

Many of the managers identified the same causes. Six managers identified the differences in maintenance skill and expertise between the technicians used in DT&E/IOT&E and the field personnel. As one manager commented:

> First, you have experienced contractors who know the system inside and out and have special test equipment. Second, you have a trained group of blue suit maintenance personnel who are better than the normal user command personnel.

Another reason given for the poor correlation in R&M data, was the difference in the testing and field environment. It is not possible to duplicate the weapon system's operational environment during development. The use of IOT&E is usually representative but still lacks some key factors. A total of five managers reported this factor. One manager stated:

> The difference is in the labs and real world environment. There's a lot of procedures that we've agreed to during those phases that perhaps misrepresent the numbers. It's basically just an environment difference...

The maintenance environment of the system is also a factor to consider. Many development programs have dedicated facilities which allow most of the maintenance to be performed inside. This way the developmental system is not exposed to the weather as frequently as the operational system. While there is little that can be done to make the development environment more operationally representative and it appears the use of contractor maintenance is the norm. The impact to R&M measures' accuracy created by data collection can be worked.

The issue of data collection during development testing was acknowledged by three managers as a source of the R&M disparity. One manager explained it as:

> The data collection early on with the contractor and SPO guys is more likely to be flavored to getting the system to look as good as possible. Let's say you have a failure and you don't know if it's type 1 or not. We use JRMET ... and sometimes give the system the benefit of the doubt. We get rid of a lot of faults that should not be blamed on the system your testing.

As this manager further noted, the field units do not use anything like JRMET. They also do not deal with failures in the way expressed by another manager who reported:

> ... usually in our lab testing we tend to rule out a certain amount of failures. If there is a failure and a fix is identified but has not been incorporated and an item fails a second time for the same cause, we don't count it.

Several other probable causes were presented during the interviews. These were:

1. A smaller number of systems to maintain in development.
2. Contractor uses different test and support equipment.
3. Problems with initial production run like quality.
4. A spares shortfall until system reaches maturity.
5. Lack of formalized follow-up of predicted R&M data.

The most frequently identified cause for the gap in testing and field R&M data results from the numerous definitions used in R&M calculations and the measures themselves.

The issue of definitions and understanding the R&M program was discussed in seven of the interviews. "There is a difference in what we're measuring. The definition changes from DT&E to operational.", explained one manager. The R&M calculations are affected by the difference in the time factor. In DT&E time is usually total system operating time while in the field flying time is used. Several managers feel a standard definition is needed. Another manager explained, "the user's measures of merit are different than what we hold the contractor responsible for. There is no direct translation between what the user and contract consider important."

This last comment raises an important issue. Are the systems being developed to the level of R&M that the operational command wants? The literature reported that many systems are not reaching the desired R&M levels. However, many systems are meeting the contract requirements. In the opinion of three managers field R&M is as high as the development predictions but this fact is not known because of the way field data is handled. Another manager was concerned with the misunderstanding of reliability growth and reliability maturity. Many people do not understand that the predicted reliability given for a system is based on a mature system. The maturity of a new system is based [illegible] a total number of flying hours and to reach this goal may [illegible] a few years after initial system delivery. In the mean time the system and subsystems reliability should be compared to the projected reliability growth curve. The mature system R&M values will not be achieved with the first systems deployed. The importance of understanding and standardizing the R&M definitions was provided by an acquisition manager when he stated, "Half the problem with the R&M program is understanding the definitions". After discussing the problems and reasons for poor R&M, the next area to look at is how to improve R&M.

Improving System R&M. Interview question 18 was used to provide the data for this section. The problem of low system R&M must continue to receive top level management attention. System R&M is to be considered equal to cost, schedule, and performance during acquisition programs. These statements provide the answer to improving R&M according to three of the acquisition managers interviewed. While R&M 2000 and other directives have continued to push system R&M, the interviews indicated that more emphasis is needed. The response from one manager indicated that improving R&M still comes down to the issues of money and priorities. He suggested:

> More money has to be allocated for that purpose [R&M]. A lot of times when we get into a crunch for what ... to spend our bucks for, it is easier to justify changes for performance than R&M.

This same manager provided an explanation as to why performance is above R&M when he commented:

> You want the system to perform first then you can work the problems of how to fix it and make it last longer. You can delay R&M. ... The whole system is geared that way. Your program will be killed quicker for performance problems than for R&M.

Placing a higher priority on performance than R&M early in the acquisition program is the type of decision which may prevent significant R&M improvements. Managers have to put emphasis, time, and money towards R&M issues at the start of the acquisition cycle in order to obtain R&M improvements. The most reported means to improve R&M focused on contracts, incentives, and valid requirements. The thoughts of five managers on improving R&M can be understood by reviewing one manager's comments:

> The biggest benefit and most cost effective approach to improved R&M is in obtaining detailed user requirements for R&M. Product specifications ... that detail what has to be produced coupled with a contract to enforce compliance with the specifications on the contractor.

Several managers reported that the use of incentives possibly in the form of warranties was helpful in improving R&M in their program. Besides better specifications and contractor incentives, proper planning and execution of reliability growth testing and the use of a TAAF phase during development will help identify potential system problems. These techniques can also expedite system maturity. In one program by working producibility issues to reduce costs and improve quality, R&M also benefited. Another area was mentioned that involved working with the system after deployment. Two managers recommended the need to keep design engineers and some development people on the system through the maturation phase to work system problems that occur after deployment.

Summary

This chapter provided the results of the thesis data collection effort. Based on the literature review findings successful concurrent programs were identified. Some of these were the Thor, Titan, and Polaris ballistic missiles. The use of concurrency was shown to be periodically accepted and rejected because of acquisition program problems with cost and system performance. The primary benefit of concurrency is a shortened acquisition cycle; however, this also increases program risks and creates problems. Some of the potential problems in concurrent programs are poor performance and reliability. The low correlation between testing and field R&M measures was shown to be a problem caused by several factors which included the R&M definitions and calculations.

The data collected from the interviews was presented and showed that the managers reported some of the same information as the literature. The acquisition managers reported the primary benefit of concurrency as a shorter schedule. This benefit is also a major element in the primary problem of concurrency, system retrofit. Eight hypotheses were evaluated for different factors that could potentially affect system R&M. This evaluation was performed for the individual managers' responses and by program. Additional information was collected on factors which the managers felt impacted system R&M. Through an interview question the managers' views on how to improve system R&M showed better contract specifications and contractor incentives as the most frequently provided response. The conclusions and recommendations based on this thesis data base are contained in the next chapter.

V. Conclusions and Recommendations

Introduction

The conclusions and recommendations presented in this chapter are based on the researcher's findings from the literature review and interviews of acquisition managers involved with concurrent acquisition programs.

Concurrency is an acquisition philosophy that has been incorporated by DOD since its first military use on the ICBM program. When defined as an acquisition strategy, concurrency is an overlap of some or all of the acquisition process phases. These phases are concept exploration, demonstration and validation, full scale development (FSD), and production/deployment. The use of concurrent acquisition programs has been debated for the last 30 years. The research indicates that all major acquisition programs use some degree of concurrency. As demonstrated by all the weapon system programs used in this study, the phases most frequently overlapped are FSD and production/deployment. Over the years many successful weapon systems have been developed using concurrency. Some of these systems are the Atlas, Titan, Thor, and Minuteman ICBMs. Also, several aircraft programs successfully used concurrency and produced effective systems including the U-2, SR-71, F-15, F-5E, and F-16C/D. Despite these numerous successes several concurrent acquisition programs have been considered failures.

Concurrency Benefits/Problems

The reasons for the continued discussions about concurrency can be found in the reported benefits and problems.

Concurrency is used primarily to shorten the acquisition cycle and reduce acquisition costs. Concurrency is usually planned from the beginning of the acquisition phase. It has also been used to meet firm IOC dates once a program schedule has slipped due to technical and/or funding problems. Efforts to reduce the length of time to acquire new weapon systems is also the cause of many of the problems associated with concurrency. Acquisition programs with optimistic schedules which experience technical problems and/or a slip in the availability of test articles result in concurrency related problems. Some of these problems are inadequate test data for program decisions, system production and deployment with incomplete DT&E/IOT&E testing, system retrofits, poor performance, use of interim contractor support (ICS), and low system R&M.

A major concern of acquisition managers of concurrent programs is the need for system retrofits to improve system performance and/or R&M. The requirement for retrofit of production articles and the use of ICS may negate any cost savings produced by concurrent acquisition. The end result of a concurrent acquisition program, success or failure, depends on the decisions and skills of the program managers. As previously mentioned, there have been several successful and unsuccessful concurrent programs. However, the scope of this research will not allow further comment in the area of overall program outcomes. This study is limited to reviewing the impact of concurrency on system R&M.

Concurrency's Impact on R&M

The proven techniques for developing R&M such as reliability growth testing, parts derating, burn-in, and a TAAF phase increase the development time and cost of acquisition programs. Consequently, the primary benefits of concurrency, a shorter schedule and lower acquisition cost, are in direct conflict with improving weapon system R&M. Also, a shorter acquisition cycle provides less time to fully develop system performance. Since system performance is still the primary element in obtaining funding and ensuring program continuation, acquisition managers, senior Air Force leadership, and Congress focus on this element. Therefore, system R&M development receives secondary consideration. Concurrency also impacts R&M through its impact on other factors.

Other Factors Affecting R&M

Concurrency impacts the factors in this section by reducing the time to develop and accomplish them. The research shows that the existence and impact of the following factors is dependent on the individual acquisition program.

Contractor Personnel. Today's acquisition programs use contractor maintenance during system development. The use of contractor personnel to perform system maintenance during DT&E and sometimes during IOT&E results in lower system field R&M measures than the R&M measures demonstrated during testing. This reduction in field R&M is the result of the lower skill and experience levels of the user command maintenance technicians. The negative impact to R&M of this factor will be eliminated as user personnel gain experience on the weapon system. Acquisition programs for weapon systems, like missiles, which have little organizational and intermediate level maintenance will not experience any negative R&M impact from this factor. SPO and AFOTEC acquisition managers consider the use of contractor maintenance as a factor which influences R&M while DPML personnel feel there is no problem.

Support/Test Equipment. Concurrent acquisition programs do not have support or test equipment, which is projected for field use, available for DT&E/IOT&E. This research produced inconclusive data as to the impact on R&M measures in all programs. The data indicates that the potential exists for negative impacts to field R&M measures. The interviewees did not agree on the potential R&M impact.

Tech Data. In general concurrent acquisition programs will not have Air Force type tech data available during testing. This is especially true if contractor personnel are performing system maintenance. SPO and DPML personnel do not feel that a lack of tech data during DT&E/IOT&E will reduce the accuracy of R&M measures. However, AFOTEC personnel disagree with this assessment.

DT&E/IOT&E. Concurrent aircraft modification programs have incomplete DT&E/IOT&E prior to the production decision. This factor reduces system field R&M measures when compared to testing demonstrated measures. In some cases acquisition programs involving modifications will have a production decision before the start of DT&E/IOT&E. This study showed that the acquisition programs developing a missile and pod completed planned DT&E and IOT&E prior to the production decision. However, additional DT&E/IOT&E was needed to evaluate fixes for problems found during the initial testing phases.

Design Freeze. While some concurrent acquisition programs have a design freeze for IOT&E, there is no impact on system R&M. In today's acquisition environment a system design freeze depends on the individual acquisition program.

ECPs. Concurrent acquisition programs have open/untested ECPs at the time of the production decision. While AFOTEC personnel feel that open/untested ECPs will reduce the accuracy of R&M measures, SPO and DPML managers do not share this concern.

TAAF. When an acquisition program has an incomplete TAAF phase, the weapon system will have lower system

R&M measures in the field than the testing demonstrated measures. The non-aircraft programs used in this study showed that they will complete their TAAF phases more often than aircraft programs.

Other Issues Affecting R&M. An important factor which influences a weapon system's R&M and was not covered by the thesis hypotheses is the calculation of R&M measures. The accurate determination of system field R&M is important in that it affects numerous real world issues. R&M measures are used to determine, among other items, spares procurement and unit manning posture. Currently, there is a problem in correlating the testing predicted R&M measures to the field results. Many plausible explanations exist for the disparity in R&M measures. The main issue is the differences in understanding what and how R&M is measured in the developmental and operational environment. During development reliability is presented as an MTBF derived from chargeable failures and system operating time. While operational reliability is calculated as an MTBMA which uses the number of system failures and flying time. A system MTBF is sometimes used in the field. This MTBF measure removes some of the failures used to calculate MTBMA, but is usually still lower than the testing demonstrated MTBF.

Most acquisition managers feel that R&M goals have been contractually met and through system maturity the predicted R&M measures will be achieved in the field. The literature shows that the required system field R&M measures are not being obtained. This real world problem which impacts system availability, combat capability, and numerous logistics areas needs to be corrected.

Another issue which could contribute to the problem of low system R&M was identified during this study. Acquisition managers in the same program and managers in general did not agree on the impact of the hypothesis factors on system R&M. This disagreement will result in some factors which affect R&M not being worked.

Recommendations for Better R&M

While certain development and testing techniques can improve system R&M, the Air Force must first develop a standardized set of definitions and calculations to determine R&M measures. The importance of R&M to system availability and combat capability makes it imperative that testing demonstrated system R&M be equal to the field R&M results. During system development and testing all failures that occur and could occur in the operational environment should be included in the R&M calculations. Repetitive failures should not be eliminated from R&M calculations because a proposed fix is not developed and incorporated in the system at the time of occurrence. Most fixes only extend the time between failures, they do not eliminate them. The definitions and calculations for contracted R&M

measures should be established so that they duplicate those used in the operational environment.

Once accurate R&M definitions and calculations representing the field environment are developed. They must be placed in acquisition contracts to ensure that contractors are aware of the R&M requirements. The key elements needed to produce the high levels of R&M required in weapon systems are senior management support for R&M, time to test and develop R&M, and the funding to obtain R&M.

System performance will continue to be the initial driving element in weapon system acquisitions. Therefore, program schedules may require additional time to test and evaluate system R&M. The inclusion of a TAAF phase in each acquisition program will improve system R&M and will help the system reach maturity early in its operational life.

Recommendations for Additional Research

The following recommendations are suggested for future research. This study showed that several acquisition managers concurred with the hypotheses. Also besides the hypothesis factors, other factors were identified which may negatively impact R&M. Additional research is needed to expand the data base. A study to determine the opinions of additional acquisition managers is one possibility.

Several differences existed in the factor's status and impact to R&M between the aircraft and non-aircraft programs used in this study. Recommend additional research on the structure and flow of the acquisition program plans to determine the reasons for the differences.

Another recommendation for study is to look at the differences in R&M definitions used in the developmental and operational environments. This study should focus on developing new contractual definitions that represent user requirements for R&M, possibly as an MTBMA.

Since one of the primary benefits of concurrent acquisition is cost savings and a major problem is system retrofit, this area warrants investigation. Retrofit of production articles can be costly and these may eliminate any development savings. Recommend a study to look at the cost of system retrofits in relation to the projected savings of concurrency.

The results of this thesis show that the problems of improving R&M are affected by concurrency but only through other factors. Continued study to find ways to control the factors will improve system acquisition. This study is a start.

AD-A187 030 THE USE OF CONCURRENCY IN THE ACQUISITION PROCESS AND ITS IMPACT ON RELIA..(U) AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL OF SYST.. J A ROSS 2/2

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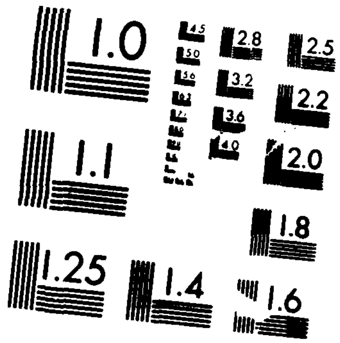

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

Appendix A: Personnel Interviewed

Beavers, Lt Col Jeffery C.	Test Manager Advanced Systems Headquarters AFOTEC
Bock, Maj Larry K.	LANTIRN Acting DPML
Eckert, Col John S.	Deputy System Program Director Deputy for B-1B
Gillette, Capt David	F-15 Integrated Logistics Support Operations Branch Chief
Harland, Mr. Billy C.	Deputy Director, Strike SPO Deputy for Reconnaissance/Strike and Electronic Warfare Systems
Hiatchi, Col Melvin	Director of Integration and Tests, F-16
Horner, Col John C.	Director of Logistics/Deputy Director for Logistics, F-16
Jordon, Lt Col Larry M.	Director of Operations B-1 FOT&E Test Team
MacDonald, Lt Col Arthur S.	F-16 LANTIRN OT&E Director
Miranda, Col Frederick J.	Director of Acquisition Logistics, B-1B
Monaghan, Maj Jeffery C.	Deputy for Operations F-15E OT&E
Schnick, Maj Robert H.	AFOTEC F-16 MSIP Test Director
Shearer, Col Richard	Director Maverick System Program Office
Stephens, Maj Boyd	Assistant DPML for Maverick
Tuck, Mr. Frank	F-15 Deputy System Program Director Deputy for Tactical Systems

Appendix B: Interview Question 1

The following information was taken from interviews. Bracketed material was added by the researcher.

What is your general assessment of the use of concurrency in acquisition?

Manager 1

The goodness or badness of it [concurrency]...will have to wait to see the impact when we meet IOC. Other factors will overcome some concurrency problems.

Manager 2

A generic response. The book says your not supposed to do it but the real world says you have to do it. It's a fact of life. Concurrency is not altogether bad but it is high risk.

It was appropriate for this program since it was not a new state of the art. Some concurrency worked on this program and saved money.

Manager 3

Not a very smart idea. We should not be forced into concurrency. However, the way the real world is we must use it. By having proper cooperation between the developers and testers, concurrency can be made to work.

Manager 4

Concurrency cuts down on system lead time but makes management of the program difficult.

Manager 5

Generally, I think it's almost mandatory that you have some level of concurrency with zero concurrency you would never get anything done. You need some level of concurrency. In the long run concurrency is going to help keep down cost and get systems into the field earlier.

You buy some problems with concurrency. Things will get out of sync and you'll be producing hardware and not be able to get all the changes into it [system].

Manager 6

It's a way of life. It's something we have to do to save money but there is a cost of doing business with concurrency. You end up with a lot of retrofit in the field.

Manager 7

Having been on several programs one of which was non-concurrent, concurrency in today's environment is almost a necessity because of the resources and monetary values involved with new weapon systems.

Manager 8

Concurrency should be avoided whenever possible. In our program the capability to build the aircraft was there but logistics had been deferred and had to be developed. This created a lot of configuration problems.

[Concurrency] may result in a large amount of interim contractor support.

Design changes of the system generated by new user requirements are difficult to incorporate and this problem is compounded by concurrency.

Manager 9

I think for most of the programs we use concurrency most of the time. The primary reason for it being to shorten the schedule for acquisition.

Manager 10

I think it [concurrency] is necessary. It has some disadvantages but I also think it has some advantages. It's about the only way in the real world that you can do it [acquisition].

You don't have any choice you use it mainly to stay in some sort of budget and schedule. You might start out with no concurrency but before you know it you will have concurrency.

Manager 11

I think it is best for some programs and inappropriate for others so it must be looked at carefully. Concurrency's success depends on the quality of management in the SPO. They must be able to anticipate the problems and get the contractor looking at them [problems] before they happen.

Manager 12

From the way our programs are going now and the length of time it takes to develop systems, to get anything fielded now it is almost inevitable that you are going to have concurrency.

So I don't necessarily see it as bad.

Manager 13

It's the only way to go, if we're going to keep the acquisition process going and keep pace with technology. Technology is moving so fast that if you don't use concurrency the user can't get what he needs in the system in terms of technology.

The type of program has to be looked at when you consider using concurrency.

Management and coordination of the program is very important in making concurrency work.

Manager 14

Concurrency has helped my program. It is important in that it provides the ability to identify operational [field] problems early.

Manager 15

Concurrency is neither good or bad it depends on the system. With a low risk/technology system the use of concurrency should not cause any problems. A high risk/new technology system should not use concurrency. However, you must look at how rapidly the technology is changing. Using a non-concurrent program in a rapidly changing technology system may result in deployment of an obsolete system.

I don't see concurrency as bad.

Appendix C: Interview Question 7

The following information was taken from interviews. Bracketed material was added by the researcher.

Who was responsible for the maintenance of your system during DT&E and IOT&E and at what level? (organizational, intermediate, depot) If the contractor, does this bias the R&M data?

Manager 1

The contractor was responsible for all three levels.

I don't think this biased R&M data because we have Air Force blue suiters there. We have JRMET, AFOTEC representatives, and Test Force personnel to overview the data.

Manager 2

Largely contractor supported.

Using contractor personnel could be a factor in causing biased R&M on a new system, but in our case a new version of the current system it did not affect it [R&M data].

Manager 3

During DT&E maintenance was performed by the contractor. For IOT&E we had some contractor support and transitioned to blue suit maintenance.

There was no bias in this program's R&M.

Manager 4

In the DT&E phase the contractor did maintenance on the new equipment with crew chief assistance. OT&E has some contractor support with mostly blue suit maintenance.

Contractor personnel may bias data.

Manager 5

During test and development the contractor was responsible for maintenance. Our system has very little maintenance in the field.

I don't think contractor maintenance biased R&M data. We're seeing better [R&M] in the field than the contract reported. This is an unusual circumstance.

Manager 6

In DT&E the contractor performed all levels of maintenance.

I have no evidence of bias.

Manager 7

Depending on the type of testing done on the aircraft, at the organizational level some systems were maintained by the contractor and some by the Air Force. Intermediate level was done by the contractor.

Does not result in bias.

Manager 8

A combination of contractor and Air Force blue suit at the O-level. At the I-level it was interim contractor support.

Yes, it can result in biased R&M because of skill differences.

Manager 9

We had contractor maintenance on some systems and as much as we could we tried to have Air Force at least over the shoulder maintenance, we're talking about O-level. For I-level most of the maintenance was contractor.

There may be some limited bias since we used both contractor and Air Force personnel.

Manager 10

The contractor at the O-level, the I-level, and depot level.

The contractor has to bias it [R&M data] a little because he has highly qualified people compared to the average GI. He most likely has higher paid more experienced people and that would make the reliability and maintainability picture a little brighter.

Manager 11

The contractor totally.

Yes, using the contractor biases R&M. Also, data from OT&E is biased because of testing on FSD items.

Manager 12

At the test sites it will be the contractor. We either have ICS or support contracts where the contractor comes in and as part of his development program shows that his support equipment is actually doing the job. We're also trying to become organic.

Yes, it biases the maintainability data more than reliability data. Your going to have a failure regardless of who fixes it, but then you might not necessarily see some of the problems with your support equipment or some of the problems with training. Your equipment will tend to get fixed quicker than in the real world.

Manager 13

We had heavy contractor involvement in DT&E. Using command and Systems Command blue suiters were also used to perform maintenance and evaluations of the system during our combined DT&E and IOT&E phases.

I'm not sure that using contractor personnel biased the R&M data. It could in some ways but it is not big since very little R&M data comes from DT&E. IOT&E data is more important in evaluating and proving R&M.

Manager 14

We had two groups performing maintenance on our system both the contractor and Air Force. The determination as to which group worked which system was dependent on the type of testing and the level of modification. During IOT&E only Air Force personnel were used.

There may be some bias.

Manager 15

We used both contractor and blue suit maintenance.

Using contractor personnel may bias R&M data but only in the initial deployment stage because the Air Force personnel have not had the chance to build up the same system experience as the contractor.

As the system reaches maturity and the blue suiters get more experience the R&M predictions should be met.

Appendix D: Interview Question 14

The following information was taken from interviews. Bracketed material was added by the researcher.

Did concurrency reduce your ability to use a test, analyze, and fix procedure to identify potential reliability problems?

Manager 1

No, I don't think so. We had problems in the fact that we didn't have enough assets in flight test that we could sit there and say OK we had a fault, go out and test it, come up with a fix, and institute it back in. Of all the items we had identified in flight test and development that needed to be fixed [they] weren't going to be implemented until production, so that was an issue. That wasn't a problem of concurrency. We had limited assets during development.

Manager 2

No. The procedure has continued to be used to further enhance the system.

Manager 3

Yes, it impacted TAAF. There were some technical problems experienced and this resulted in IOT&E, DT&E, and maturity problems. Some fixes had to be checked in IOT&E not DT&E.

Manager 4

Concurrency has not caused any problems for TAAF. We will coordinate DT&E and IOT&E requirements to minimize the potential impacts.

Manager 5

I can relate that [TAAF] to concurrency but I'll give you another thought on the matter. TAAF is an excellant tool during development testing. Unfortunately,our system is so politicized that the risk of a failure has become astronomical. TAAF maybe the cheapest way to find out what's wrong and to go ahead and fix it. If you have failures people will talk about cancelling your program and have a memory that things are terrible.

Manager 6

Yes, definitely because by the time you figure out what to test, analyze, and fix you have already built in a delay where you have units in the field that are unmodified with the fixes. So you either have to come back and do a retrofit or live with 2 or 3 different configurations which causes problems in configuration management in the life cycle of the system.

Manager 7

We didn't use TAAF generally on black boxes. We used developmental reliability qual tests, maintainability demos, and production reliability demos. Those specifications were a lot harder than TAAF to get through, especially for tests like the production reliability qual tests. If you found a deficiency in a box the contractor had to bring all the boxes already produced up to that point. This was at the contractor's expense. There were lab threshholds that had to be met.

Manager 8

We used a lot of test, analyze, and fix on individual systems but this was in the lab. We could have used more [TAAF] if we had more time to test before we went into production. The test, analyze, and fix we did do was very effective.

Manager 9

I don't think it did. Only for some of the systems did we use a test, analyze, and fix technique. When we did, it did not appear that concurrency affected that method.

Manager 10

I don't think so. We did a lot of test, analyze, and fix. I better qualify that a little bit, some of that [TAAF] was for reliability and some was for improving performance. Concurrency didn't cause us not to be able to do TAAF.

Manager 11

Yes, primarily in only one part of the system. Some problems identified in testing and fixed could not be corrected in the test articles and retested before production.

Manager 12

No, but what your going to find is we're out there flying equipment while we're still in the lab doing reliability growth programs. So we're still using it [TAAF] but it's just a concurrent phase. We have lab testing going on at the same time we have operational testing going on.

Manager 13

No, I think we did a lot in R&M and operational areas. I think there may be some reluctance to make some of the changes because of cost.

Manager 14

Yes, the schedule only allowed a short analyze period. This made it hard to really evaluate the full system.

Manager 15

We didn't use TAAF on the whole system. There was some work for reliability on the subsystems with no problems caused by concurrency.

Appendix E: Interview Question 16

The following information was taken from interviews. Bracketed material was added by the researcher.

What are the primary benefits of a concurrent program?

Manager 1

Concurrency allows you to meet a schedule. If you have problems in development and I'm not saying just development problems, but in our case funding problems that cause you to stretch out development, by having concurrency you can still meet that end item schedule, IOC. It allows you to absorb some program problems upfront and still meet a delivery date.

Manager 2

Schedule a very real fact of life in any program, a shorter schedule. By saving years on the front end of a program it is easier to get funding even though you put the assurance that R&M is correct at risk.

Manager 3

A distinct benefit is getting operational expertise involved early in the program. This allows fixes to be geared to field operational experience and need.

Manager 4

Concurrency provides a shorter schedule. Gets equipment in the field faster and reduces the chance of program cancellation. You can always go back and fix it once you have it.

Manager 5

Primarily schedule is a big benefit. If you did anything sequentially by the time you fielded a system it would be overcome by technology and you wouldn't get it fielded. The second is cost.

Manager 6

Saves money for the overall program and shortens the development cycle.

Manager 7

Obviously cost, hopefully schedule, and I think performance.

Manager 8

Your able to field weapon systems quicker and avoid political turmoil and budget problems.

Manager 9

The primary benefit is schedule.

Manager 10

Improves schedule and the acquisition cost, if it's done smartly, is reduced. It saves money by getting the job done and over with instead of stretching it out.

Manager 11

Primarily, it shortens the acquisition cycle but there is added risk. Good program management is needed to provide for risk reduction.

Manager 12

Getting the system fielded quicker, in a shorter period of time.

Manager 13

You get the system out to the user earlier. The system may not have its full capabilities but we can start training our people, operations and maintenance, and begin building their experience on the system.

Manager 14

You get the user involved and are able to evaluate the operational capabilities of the system early. So when you get done with development you are not usually surprised by major problems in the field.

Manager 15

Using concurrency allows you to get a system in the field quicker and saves money. It is important for acquisition of rapidly changing technologies.

Appendix F: <u>Interview Question 17</u>

The following information was taken from interviews. Bracketed material was added by the researcher.

What problems are associated with a concurrent program?

Manager 1

Trying to develop and produce at the same time and you may not have the final item developed before you go into production. In our program ... concurrency is not as big an issue. The first few production items are being used for TO development, training, and used in house for reliability qual testing. The first production units to the field are still a few years out, we're still in development. This allows us to incorporate significant developments into the first units going to the field.

Manager 2

There is a problem in assuring that R&M is going to be what it needs to be for the user in the field as opposed to what you may have demonstrated during the current test phases.

We had problems with new test equipment which passed all qualification tests in the contractor facility. However, in the field it had very poor reliability.

Manager 3

If concurrency is planned from the beginning it can only be a good way of doing business.

When you are driven/forced into it, the pressure to complete testing to meet delivery hinders DT&E personnel in accomplishing their job.

Manager 4

Concurrency makes a program difficult to manage. It is hard to ensure that everything gets done and is moving in the right direction.

Manager 5

There are problems with support equipment.

Mostly, you'll find things that just don't work. It will be mandatory to go back and retrofit sometimes.

Systems may be delivered with some equipment not available at the time of delivery.

Manager 6

The lack of the ability to do adequate maintenance planning early enough and to buy support equipment and spares in adequate quantities to support the first deliveries.

It impacts our ability to get reliability testing and maintainability testing accomplished and then incorporate any fixes...

There are negative impacts on virtually every ILS element.

Manager 7

Extremely tight schedules with almost no leeway.

Sometimes there is a degree of risk associated with system performance.

We're constantly slighly late getting the right configuration of support and test equipment out to meet the system and that is hampered by concurrency because we're just barely finishing up development before we start production.

Manager 8

The biggest problem with concurrency in our program was that systems were fielded before support equipment, tech data, and engineering data were available.

Results in more retrofits of the system after production.

Manager 9

Problems you would expect that things don't get fixed correctly before production decisions are made.

Production decisions are made on phase designs rather than final designs.

There is a shortening of the test and evaluation process.

Manager 10

Probably, somewhat of an unstable configuration that your having to make a lot of changes to, some of those can be costly but I still think overall you save money. I think you have more ECPs and the program is a little more turbulent.

Generally, you could end up with a design that could not do the job either from a performance or R&M standpoint.

Manager 11

Eventually, you pass the design hardware and software freeze points during testing. After that point, deficiencies found and fixed cannot be implemented into the production articles without retrofits.

Manager 12

You end up spending a whole lot of downtime retrofitting the systems that you have to modify because of problems you identified in the test program. You end up dedicating a lot of your people and resources to tracking the configuration of boxes that are totally different and trying to structure some turnaround programs to get the latest design in the field. For about the first two years after IOC, our whole dedication is going to be trying to update the configuration of the boxes that were fielded before we got to IOC.

Manager 13

The biggest problem is management of the concurrent issues. It is difficult to ensure the proper coordination and distribution of limited assets to accomplish development, testing, and training. Management must be able to integrate all the functions involved in the acquisition process engineering, contractor, testing both DT&E/IOT&E, R&M, and others.

Manager 14

The manager of the program will have problems in dealing with all the varying inputs and in deciding when it is appropriate to bring them into the program. This carries over into selecting the proper time to dedicate resources and at what issues. Some of these inputs come from design requirements, R&M issues, development testing and evaluation, operational testing and evaluation, and may include static displays and system orientation visits.

Manager 15

You can't always get the support/test equipment and tech data developed and out to the field with the system.

There will probably be retrofits required to fix design deficiencies and to bring the system up to full capability after production deliveries start.

It takes a lot more people to do it simultaneously. There are a lot of things happening at once. Requires more manpower.

Appendix G: Interview Question 18

The following information was taken from interviews. Bracketed material was added by the researcher.

What needs to be done to improve system R&M during acquisition?

Manager 1

They've done that recently. R&M has been made an important area of program management but until it is impressed on program management along with schedule and cost it won't be an issue. Continued emphasis of R&M is important.

A good warranty on the system which forces the contractor to think about R&M areas. The system has to reach the required R&M, otherwise he [contractor] will have to do the repairs.

Manager 2

The testing environment must duplicate the real world as much as possible. In our program a test set met the mil standard qualification levels and tests in the lab but failed to reach acceptable performance levels in the field.

Manager 3

A lot of things are being done from R&M 2000 to training of acquisition personnel. Continued emphasis from top level management about the seriousness of R&M improvements.

Manager 4

The biggest benefit and most cost efficient approach to improved R&M is in obtaining detailed user requirements for R&M. Product specifications must be written that detail what has to be produced coupled with a contract to enforce compliance with the specifications on the contractor.

Manager 5

As you approach the end of FSD, you should plan a phase to redesign for producibility and this will help R&M. In our program by working producibility issues to reduce production costs and improve quality, R&M benefited.

R&M has to be considered early in the program. A warranty seemed to help on our program by driving the contractor to improve R&M.

Manager 6

Find some way to give the contractor an incentive from the beginning of FSD to produce a reliable product. Coming in at a later stage is marginal payback at best and results in multiple configurations.

The way to get good reliability and maintainability is to let the contractor know in the beginning that he gets a reward or a penalty for producing either outstanding R&M performance or deficient R&M performance. Warranties are one way to do this but not the only way to provide incentives.

Manager 7

Besides designed in objectives when you first get the weapon system in the field have a structured system established with a loop back to the design and test engineers. This way for any initial problems with a could not duplicate or bench check serviceable; the box, test set in AIS, and fault isolation system can be looked at to fine tune the system once it starts performing in the field.

Manager 8

Contractual language in terms of reliability and maintainability requirements has to be a little more specific and demanding on the contractor.

Manager 9

I think the key thing is the design of R&M. Also, reliability growth testing and test, analyze, and fix need to be properly scheduled and planned.

Manager 10

One thing is to do more early real growth testing and earlier maintainability demos by bring in the user when the prototypes are being put together. This would be preliminary testing and would have to be done again later.

Another thing is once the system is delivered to the field, some of the design engineers who built the system ought to carry it through the maturation phase. This will help identify the problems that crop up after a system reaches the field, some of which you don't see in development.

Manager 11

Everyone needs to think about R&M. The establishment of R&M 2000 as the directive to improving R&M. The operational side in Systems Command needs to be educated in R&M.

Manager 12

More money has to be allocated for that purpose [R&M]. A lot of times when we get in a crunch for what are we going to spend our bucks for, it is easier to justify changes for performance than R&M.

The reliability and maintainability improvements are going to save somebody else money downstream. Everybody knows it [R&M] is good but the money isn't there. Maybe you need to set aside some logistics money and not let anyone else into it. Then that would force them [logistics] to make some of the decisions on what we can afford to have in our system.

To a large extent it is a mentality problem. You want the system to perform first and then you can work the problems of how to fix it and make it last longer. You can delay R&M. You can't get your system to production unless you prove it performs. The whole system [acquisition] is geared that way. Your program will be killed quicker for performance problems than for R&M.

Manager 14

Get some knowledgeable field wise people in to look at and evaluate the system early in the program. That is bring in the people who are going to have to do the work on the system. This will help identify potential maintenance problems in time to get them corrected before the system gets to the field.

Manager 15

If your going to do a concurrent program you might want to leave out some risky technology or have a parallel development effort [for subsystems] but that costs money. That is have two developments one that is high risk and one that is low risk, a fall back in case the high risk/ technology doesn't work out.

Researcher: What techniques such as reliability growth testing or TAAF can we spend more time doing that will help improve R&M.

I don't subscribe to the theory that R&M goes down when you use concurrency.

Appendix H: Interview Question 19

The following information was taken from interviews. Bracketed material was added by the researcher.

What do you feel accounts for the differences in R&M measures between DT&E, IOT&E, and field results?

Manager 1

One thing is that in DT&E and IOT&E you have a smaller number of systems. While in the field you have more systems doing more different missions than in test.

You develop a higher level of maintenance expertise and knowledge of the system with both the contractor's personnel and a small Air Force cadre. In the field you have a lower maintenance expertise.

The test environment is benign. The field support equipment is usually different.

Manager 2

The differences between the lab testing environment and the real world.

Manager 3

We don't have uniform definitions. From my experience on three programs, DT&E and operational personnel do not interpret definitions the same. We need a standard definition. In DT&E we use MTBF and operational needs for reliability are expressed as an MTBMA.

Test conditions are different between DT&E and IOT&E.

Manager 4

In DT&E and IOT&E the Air Force personnel used are very good technicians. This combined with the use of contractor personnel gives you very good maintenance. In the field you have lower skilled personnel.

Manager 6

As much as anything, the user's measures of merit are different than what we hold the contractor responsible for. There is a difference in what constitutes a failure. There is no direct translation between what the user and the contract consider important.

Manager 7

During DT&E you have a very select group that knows what their doing. The emphasis is concentrated on a few systems. Comparing that performance [during DT&E] good or bad to what will eventually take place in the field with the run of the mill GI... sometimes there is no relationship between them.

IOT&E and OT&E come a little closer [to the field] if they are not concurrent with DT&E.

Manager 8

I account for that in two ways. First, you have experienced contractors who know the system inside and out and have special test equipment.

Second, you have a trained group of blue suit maintenance personnel who are better than the normal user command personnel.

Manager 9

The Air Force as a community needs to standardize the definitions of R&M. In many cases we have lab values which we have rules of thumb for translating to field values but I think we need to standardize the definitions. In my experience the confusion comes about when you want to have an R&M incentive or warranty clause in the contract. You have to make sure that you and the contractor really understand what numbers to use and to measure against.

Manager 10

Part of the problem comes from the blue suiters in their handling of the system, and their experience in troubleshooting and maintaining the system.

The data collection early on with the contractor and SPO guys is more likely to be flavored to getting the system to look as good as possible. Let us say you have a failure and you don't know whether it's type 1 or not. We use JRMET to analyze and figure out where it [failure] ought to go and we sometimes give the system the benefit of that. We get rid of a lot of faults that should not be blamed on the system your testing. You don't JRMET failures in the field.

Where as later on the GIs are just filling out forms to report reliability. They are not out to give any credit to a given system. The routineness to them of reporting the reliability would have an impact. The actual reliability may be as much in the field but is preceived to be poorer because the guy didn't do the same type of [evaluation] as the guys back in DT&E would do.

Part of the reason could be the definition of a failure.

The environment in testing is not really representative of the operational environment.

Manager 11

Differences in R&M data collection. During DT&E info is collected by the contractor and can be incomplete and biased. Data from OT&E is collected more scientifically and is geared to determining R&M results. The normal field system is not appropriate for R&M and data is not screened.

I think the Air Force has failed to provide the required follow-up of the projected R&M so that it can be compared with field data.

Definitions and criteria differences between testing and operational field contribute to the variance of R&M data.

Manager 12

The difference is in the labs and real world environment. There's a lot of procedures that we've agreed to during those phases [testing] that perhaps misrepresent the numbers. It's basically just an environment difference and the fact that usually in our lab testing we tend to rule out a certain amount of failures. If there is a failure and a fix is identified but has not been incorporated and an item fails a second time for the same cause, we don't count it. Out in the real world if an item fails twice for the same thing you count it twice.

There is a difference in what we're measuring. The definition changes from DT&E to operational.

Manager 13

You don't have the normal run of the mill Air Force technician on the system during testing. You use hand picked highly qualified technicians with lots of experience.

The difference in R&M measures is caused by the difference in the maintenance personnel's skill and experience.

Manager 14

Some of the difference comes from problems associated with the beginning of the system production run. (quality)

The change in system environment from the sterile lab to the field contributes in that the system receives rougher handling.

Manager 15

I think you can take cases [that show a problem] but take our program for instance of some 6,000 different systems, parts, LRUs, and SRUs; there is only a handful not meeting their reliability growth.

One of the big problems is understanding reliability growth and reliability maturity. That is that your going to get to a certain maturity at a certain point in the life of a system. Almost everything we've got is right on the maturity curve and getting better. There are LRUs that we're going back and fixing. When you put it in perspective it's not that bad.

I don't think [a lot of people] understand reliability growth. They expect the predicted mature values to occur before system maturity.

We lay in spares, reasonably, at the mature level, not at half or a quarter of the mature level, so we don't have to buy so many. So in the mean time you set yourself up for a shortfall as you go up the growth curve.

Half the problem with the R&M program is understanding the definitions.

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Vita

Captain John A. Ross was born on 10 November 1950 in Jersey City, New Jersey. He graduated from St. Mary's High School in Perth Amboy, New Jersey. Captain Ross joined the United States Air Force in December 1969 as an Aircraft Maintenance Crew Chief. He was an honor graduate of both the three and seven level Aircraft Maintenance Technical Courses, 431X1 offered at Sheppard AFB, Texas. Captain Ross attended Eastern New Mexico University, graduating in 1978 and receiving the degree of Bachelor of Science in Psychology. In 1979 he received his commission in the United States Air Force through Officer Training School. He was an honor graduate of the Aircraft Maintenance Officer Course at Chanute AFB, Illinois. His first assignment was to Homestead AFB, Florida where he held the positions of Officer in Charge of the Maintenance Management Division, 306th and 307th Aircraft Maintenance Units. In 1983 Captain Ross was reassigned to Edwards AFB, California and was assigned initially as the LANTIRN Maintenance Branch Chief and later the Deputy for Maintenance F-16 Combined Test Force. He attended Squadron Officer's School at Maxwell AFB, Alabama in 1986. Captain Ross entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1986.

Permanent Address: 33 MacArthur Drive
Edison, NJ 08817

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BLOCK 19. Abstract

The use of some degree of concurrency in weapon system acquisition has become a normal mode of operation. There are several benefits and problems associated with concurrent programs. The recent elevation of reliability and maintainability (R&M) to a status equal to performance, cost, and schedule when evaluating current weapon systems has added to the list of potential problems experienced by concurrent programs.

A literature review was conducted which traced the history of concurrency from the Ballistic Missile Programs to the 1986 Packard Commission Report. This review focused on the reasons for the continued discussions on the overall value of concurrency. The review also looked at the impact of concurrency on system R&M. Several factors were identified which existed in concurrent programs and showed a potential to limit system R&M. In addition the study covered the causes for the variances between the system R&M measures demonstrated in the developmental and operational environments.

The researcher interviewed fifteen managers who were involved in five concurrent programs. These managers were from the following areas: the System Program Office, Deputy Program Manager for Logistics, and the Air Force Office for Test and Evaluation. The interviews focused on the managers' opinions of concurrency's use and how it affected R&M development in their program.

The results of this study indicate that concurrency does impact system development. However, the amount of impact and the applicability of the factors reviewed varies by program. Managers' opinions of the factors appear to be influenced by their position in the acquisition program. The benefits and problems of concurrency are covered. The causes for the disparity between field and development R&M measures, suggestions to correct this R&M problem, and recommendations to improve system R&M are discussed.

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